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Interim Report
for
A PROGRAM TO EVALUATE A CONTROL SYSTEM BASED ON FEEDBACK OF AERODYNAMIC PRESSURE DIFFERENTIALS

KU-FRL-490-1

Part I

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ABSTRACT

This report describes work done under a program to evaluate the use of pressure differentials in a flight control system.

The first part of the program consists of a study to determine the pressure profile around the test surface. This study was performed using two techniques:

1) Windtunnel Data (Actual)
2) NASA/Langley Single Element Airfoil Computer Program (Theoretical).

The system designed to evaluate the concept of using pressure differentials is composed of a sensor drive and power amplifiers, actuator, position potentiometer, and a control surface.

The second part of this program consists of determining the characteristics (both desired and actual) of the system and each individual component. This report, however, terminates with the desired characteristics of the system as a whole. The actual frequency response of the system could not be obtained due to the use of an inappropriate sensor.

This report describes the flight control system developed, the testing procedures and data reduction methods used, and theoretical frequency response analysis.

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LIST OF SYMBOLS AND ACRONYMS

Symbol	Definition	Dimension
C_p	Pressure coefficient	
q	Dynamic pressure	lbs, ft^{-2}
α	Angle of attack	deg
θ	Euler pitch angle	deg
δ_E	Elevator angle	deg
$\omega_{n_{sp}}$	Undamped natural frequency of the short period mode	Hz
$\omega_{n_{p}}$	Undamped natural frequency of the dutch roll mode	
ΔP	Change in pressure between lower and upper surface	lbs, ft^{-2}

Acronyms

DAS	Data Acquisition System
AFCS	Automatic Flight Control System
SEAP	Single Element Airfoil Program
SSSA	Separate Surface Stability Augmentation

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1. INTRODUCTION

1.1 PURPOSE

The purpose of this study is to provide information leading to determining the feasibility of using a differential pressure feedback signal in an airplane's flight control system.

1.2 BACKGROUND

In nearly all airplanes equipped with automatic flight controls (AFC), the control surfaces are positioned via a feedback loop with a feedback gain proportional to control surface position. Since in many instances control surface position is linearly related to the differential pressure created by a control surface deflection, this type of feedback works well.

However, in many systems, it is found necessary to schedule the feedback gain as a function of flight attitude, Mach number, dynamic pressure, or a combination thereof. (At this point in time, Mach number is not included.)

Since the purpose of any control motion is to create a certain pressure differential, it is logical to consider a system whereby control surface motion is signalled by a gain directly proportional to the pressure differential. The differential itself would then have to be sensed by a suitable pressure sensor.

This method of control surface signalling may simplify control law requirements. It may also allow for the direct control of airplane attitude relative to the total velocity vector of an

airplane. This is because such attitudes are themselves proportional to pressure differentials across lifting surfaces (Reference 1).

1.3 METHODOLOGY

This study was performed using the following three phases:

1) Pressure profile study
2) Sensor calibration
3) Frequency response and transfer function determination.

The pressure profile study is used to determine the range and characteristics of the test surface. The sensor calibration phase is needed to obtain the sensor's physical characteristics. (The actual work of this study terminated at this phase.) A theoretical frequency response analysis has been conducted; but at the time of this report, the physical testing of this phase has not begun, due to the results of Phase II.

2. SYSTEM DESCRIPTION

2.1 OVERALL SYSTEM THEORY

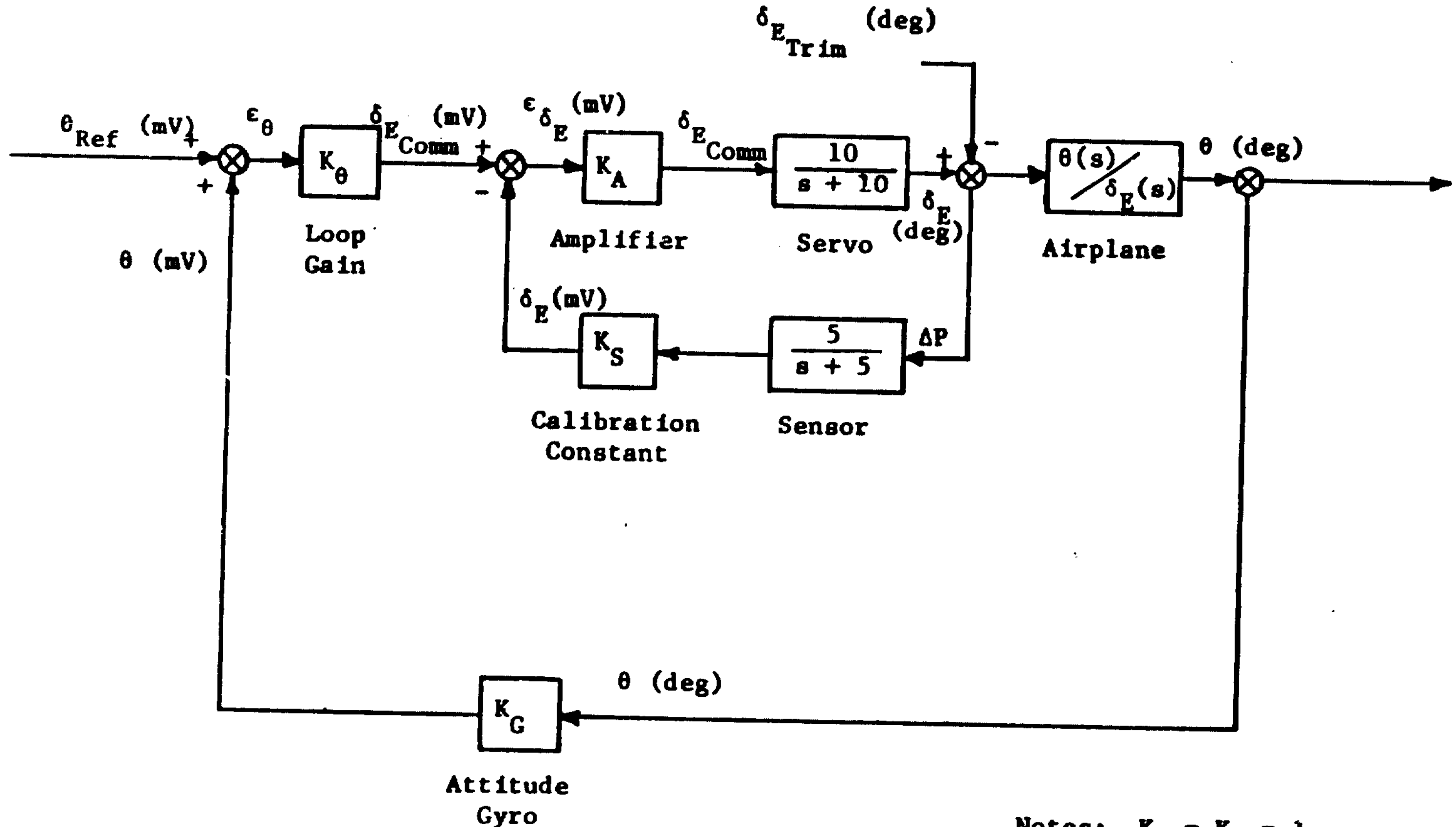
The flight control system which was designed to test the use of a differential pressure sensor is illustrated in Figure 2.1. The block diagram is a pitch attitude hold system with the differential pressure feedback for the $\delta_{E_{COMM.}}$ loop. The flow diagram of the inner loop is illustrated in Figure 2.2.

2.2 COMPONENT BREAKDOWN

The components used in the testing are listed in the flow diagram of Figure 2.2 and can be found in the appropriate drawings according to Table 2.1.

Table 2.1 Guide to Delta P Drawings

Drawing No.(s)	Component
DP-0105	Sensor
DP-0204	Sensor Circuit Schematic
DP-0204	Sensor Wiring Diagram and Layout
DP-0301	Signal Conditioner (Control Box)
DP-0204	Signal Conditioner Schematic
DP-0204	Signal Conditioner Wiring Diagram and Layout
DP-0301	Drive Amplifier
DP-0301 DP-0203	Power Amplifier
DP-0203	Power Amplifier Schematic
DP-0101	Actuator (Assembly View)
DP-0101	Position Potentiometer (Assembly View)
DP-0101	Delta P Test Surface (Assembly View)



Notes: $K_A = K_G = 1$

$K_S = .047\ q$

Figure 2.1 System Block Diagram

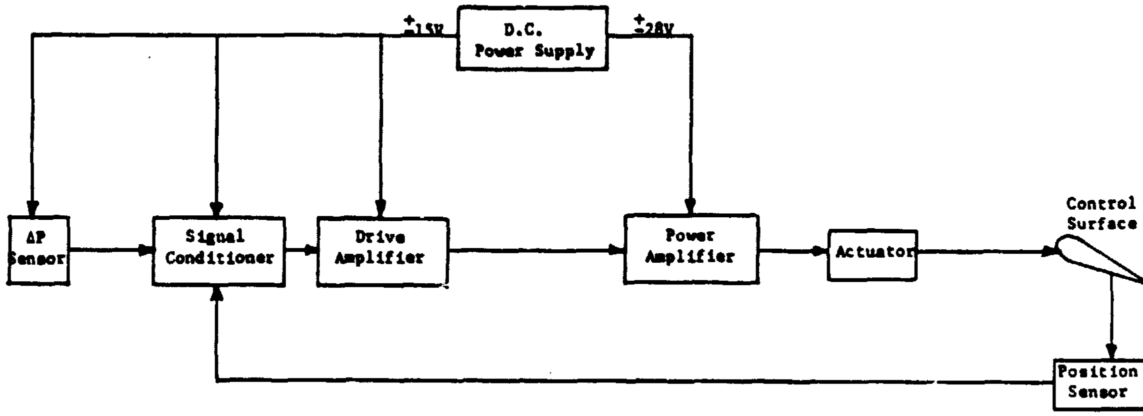


Figure 2.2 System Flow Diagram

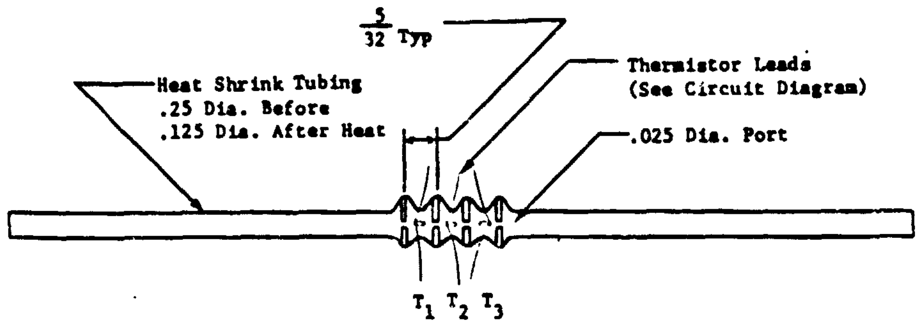


Figure 2.3 Differential Pressure Sensor

2.2.1 SENSOR

The sensor used in this study was designed by Jim Black, NASA DFRC Engineer. The sensor uses three thermistors to measure the differential pressure between the two ports. Figure 2.3 illustrates the sensor's components. The circuit diagram for the sensor is found in Figure 2.4.

The sensor, designed to be used in a wing-leveler autopilot system, operates by keeping the middle thermistor at a constant temperature. As the air flows past the front thermistor (a flow due to differential pressure), it is cooled. After passing the middle thermistor, the air is heated, thus causing the rear thermistor to be at a different temperature. This temperature difference results in a voltage difference within the sensor circuit. This difference, again, is the result of a pressure differential.

2.2.2 SIGNAL CONDITIONER

The signal conditioner in the flow diagram performs the following tasks:

1) Reads the differential pressure signal from the sensor-circuit combination
2) Monitors the position of the control surface.

The signal conditioner uses the signal from the position potentiometer to prevent a hardover condition.

The circuit diagram for the signal conditioner is given in Figure 2.5. The signal conditioner (designed by Dr. D. G. Daugherty,

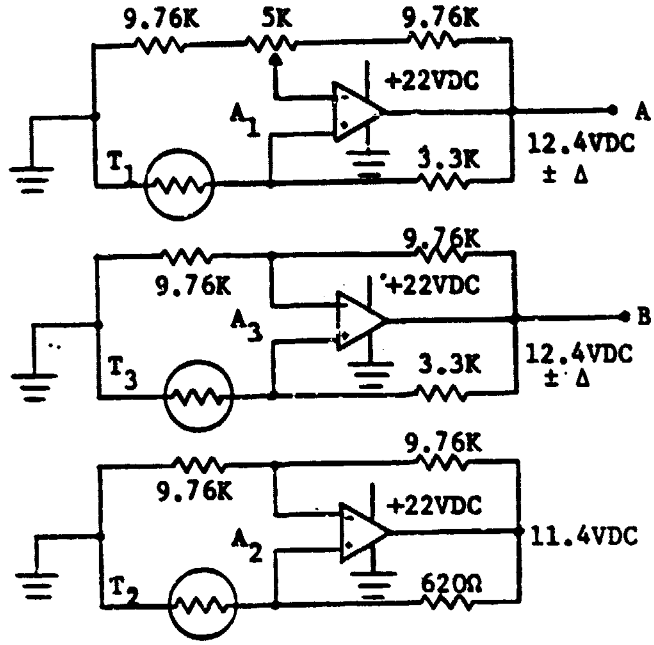


Figure 2.4 Sensor Circuit Schematic

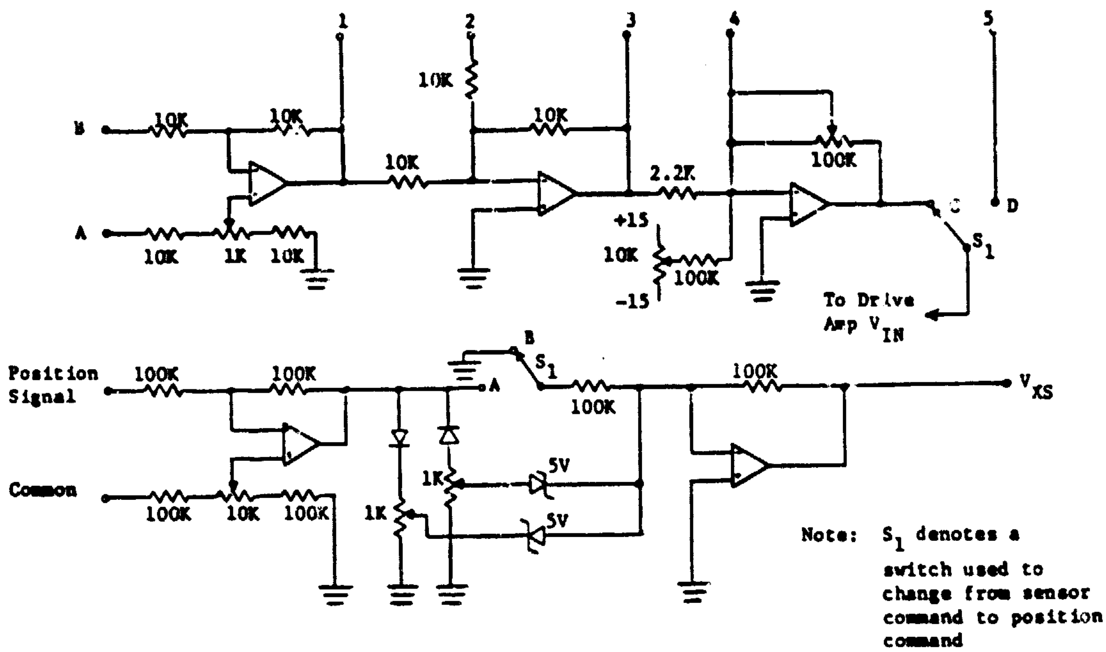


Figure 2.5 Signal Conditioner Schematic

KU Electrical Engineering Professor) was also designed to aid the frequency response testing of Phase III. To do this, test points and input terminals were included; their functions are listed in Table 2.2.

Table 2.2 Signal Conditioner Test Points and Input Terminals

Circuit Point No.	Symbol	Function
1	+P (OUT)	Differential Pressure Output Signal
2	$-P_c$ (IN)	Frequency Response Signal Input
3	$P_c - P = \varepsilon$	Error Signal
4	Comp.	Compensating Circuit Signal (if Required)
5	P.C.	Position Command Signal-Sensor can be bypassed and surface controlled using position potentiometer (LVDT)

2.2.3 DRIVE AMPLIFIER

The drive amplifier used in this study is from the NASA M99 separate Surface Stability Augmentation (SSSA) Project. The schematic of the drive amplifier may be found in Figure 2.6.

The drive amplifier uses standard op-amp methods for developing opposite phase drive signals required by the power amplifier. Discrete transistors connected as complementary emitter-followers provide the necessary drive current for the power amplifier inputs. Small (56 Ω) resistors are included in the collector circuits of

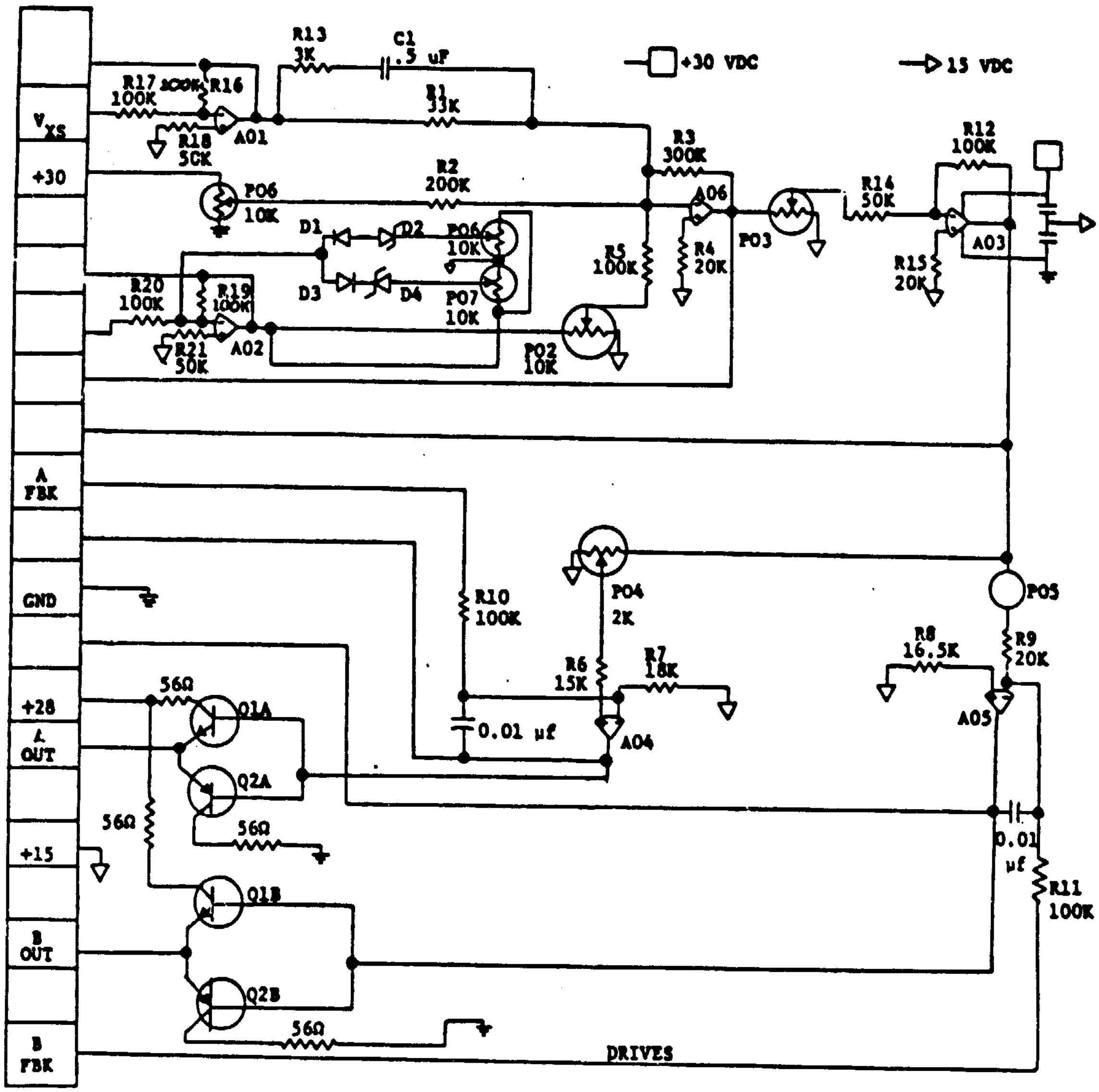


Figure 2.6 Drive Amplifier Schematic (Reference 2)

these emitter-followers as protection against mishaps during circuit testing. In normal circuit operation their function is inconsequential (Reference 2).

The drive amplifier receives the V_{IN} signal from the signal conditioner, while also monitoring the position of the surface through the V_{XS} terminal. The output then goes to the power amplifier.

2.2.4 POWER AMPLIFIER

The power amplifier used in this study is also from the SSSA project. The schematic of the power amplifier is given in Figure 2.7.

The power amplifier is a Class-B push-pull bridge configuration. This configuration was used in order to attain actuator voltages approaching ±28 volts (56 volts, peak-to-peak). Diodes are included for protecting the power transistors against inductive spikes from the actuator (Reference 2).

The power amplifier receives four (4) signals from the drive amplifier:

1) A FDBK
2) A IN
3) B FDBK
4) B IN

The A and B FDBK signals are transmitted directly to the actuator. It is these signals which drive the actuator. The A and B IN signals originate at the drive amplifier. The A and B IN signals are connected to the drive amplifiers A and B OUT terminals, respectively.

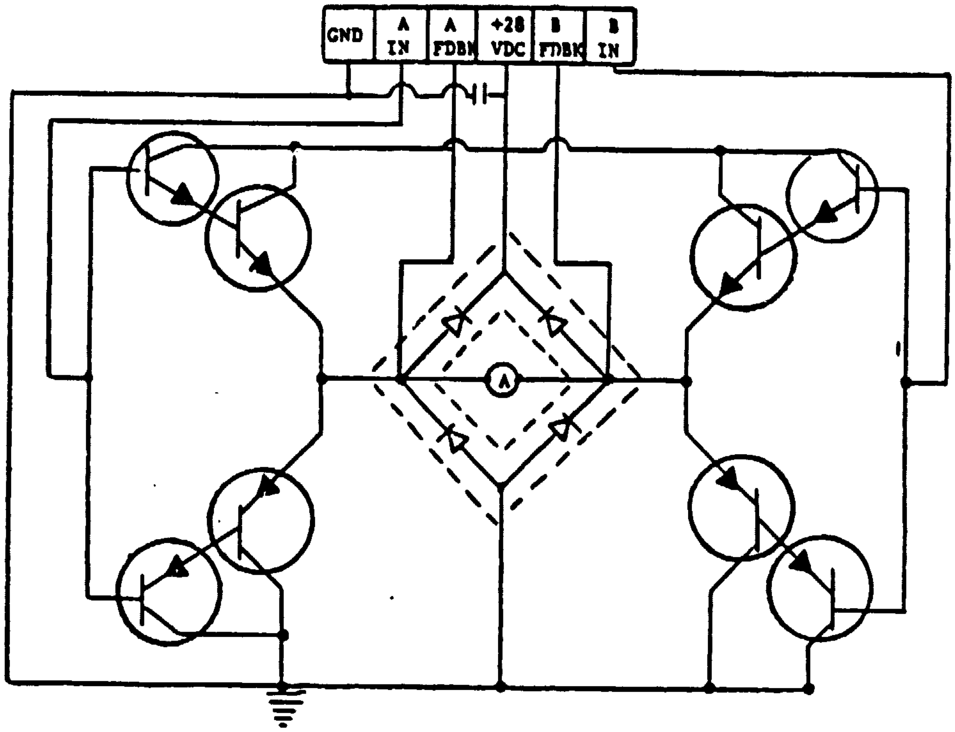


Figure 2.7 Power Amplifier Schematic

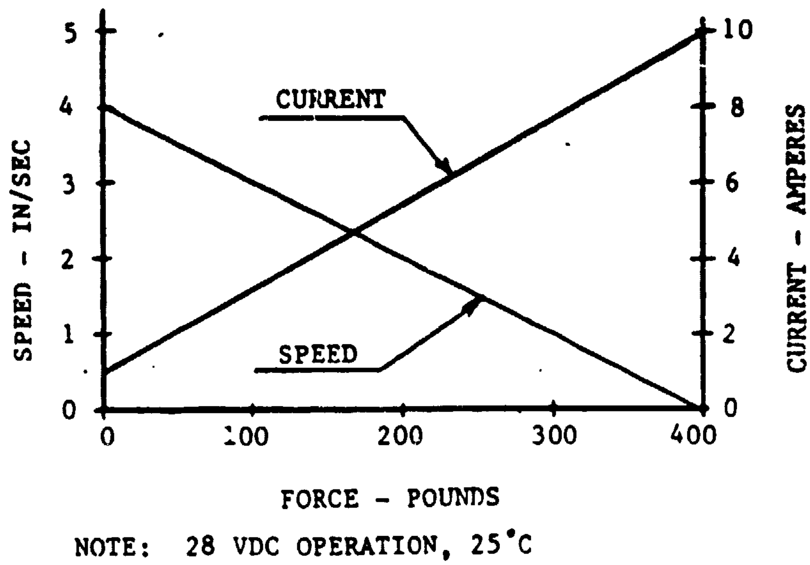


Figure 2.8 Solactor Actuator Properties

2.2.5 ACTUATOR

The actuator used in this study is the McDonnell Douglas "Solactor," Model 6023 A, also used in the SSSA project. The properties of the actuator are given in Figure 2.8.

2.2.6 POSITION POTENTIOMETER

The position potentiometer (L.V.D.T.) used in this study has the following characteristics:

1) Type: III

2) Resistance: 2K Ω ± 10%

3) Range: 3" linear: 1%

2.2.7 SURFACE AND MOUNTING HARDWARE

The test surface used in this study is the Beech, Model 60 (DUKE), elevator-trim tab assembly. The surface was obtained through the Aerospace Engineering Department at the University of Kansas. The surface and mounting hardware are illustrated in Figures 2.9 and 2.10. Also included in these figures are the actuator and L.V.D.T. Table 2.3 gives a listing of the detailed drawings of the surface and mounting hardware which are available through the Flight Research Lab, at the University of Kansas Center for Research, Inc.

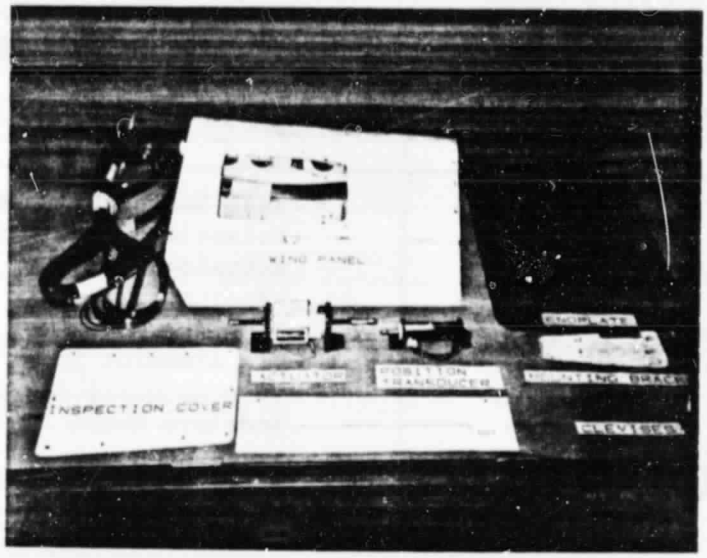


Figure 2.9 Test Surface and Mounting Hardware

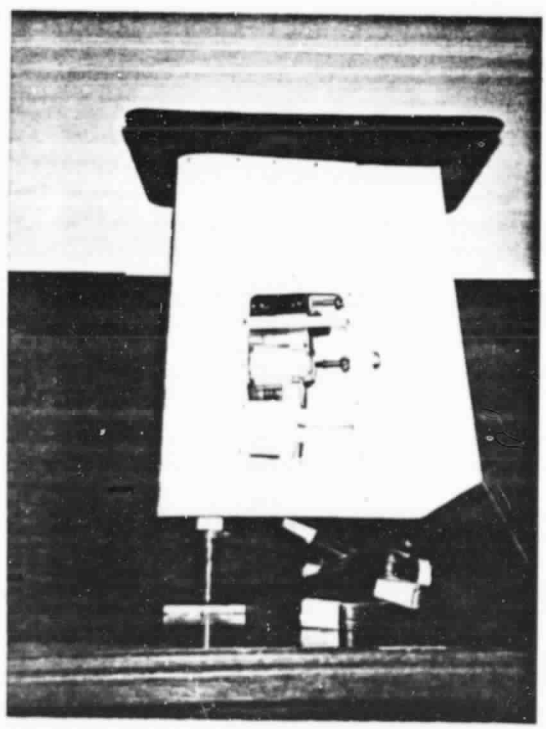


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Figure 2.10 Test Surface (Assembly View)

Table 2.3 Delta P Surface and Hardware Drawings

Drawing No.	Item
DP-0101	Test Surface (Assembly View)
DP-0102	Potentiometer Clevis
DP-0102	Actuator Clevis
DP-0102	Windtunnel Mount
DP-0102	Mounting Rib
DP-0103	Aft Actuator Mount
DP-0103	Fore Actuator Mount
DP-0104	Endplate Mount
DP-0104	Endplate

3. PHASE I: PRESSURE PROFILE STUDY

3.1 PURPOSE

3.1.1 BASELINE DATA ON PRESSURE DISTRIBUTION

Because of the uniqueness of the airfoil used, a pressure profile study is necessary to obtain baseline data on the pressure distribution at specific angles of attack and flap deflections. The data obtained during this study are used against the theoretical analysis of Section 6.1. If the pressure distribution can be predicted, then a windtunnel pressure profile study can be eliminated.

3.1.2 SENSOR LOCATION

The major objective of the pressure profile study is to determine the location of the differential pressure sensor.

The control system illustrated in Figure 2.2 is designed primarily for flap deflection sensitivity; however, provisions have been made in the signal conditioner control box for angle of attack sensitivity. The selection can be made through a switch mounted on the control box.

The locations of the sensors are determined using the results of the data reduction. These results are best summarized using the graphs found in the data presentation of this report. These graphs show how the change in the pressure coefficient, $\Delta C_p = C_{p_{LOWER}} - C_{p_{UPPER}}$, changes with angle of attack and flap deflections for 13 chordwise locations.

The criteria for selection are as follows:

Sensor No. 1: a) Sensitivity to angle of attack

b) Least sensitivity to flap deflection

c) Consistent linearity

Sensor No. 2: a) Least sensitivity to angle of attack

b) Sensitivity to flap deflection

c) Consistent linearity

With sensors at these two locations, both angle of attack and flap deflection can be sensed separately and accurately within the range of linear aerodynamics.

3.1.3 SENSOR RANGE

Results from the pressure profile study are also used to determine the range of pressure required to be sensed by the sensor. It is this characteristic which the sensor does not have.

3.2 FACILITIIES AND HARDWARE

3.2.1 WINDTUNNEL

All testing of the surface was performed at the University of Kansas Aerospace Engineering Department's 3' x 4' subsonic windtunnel. Facilities include a 60 tube manometer, 26 of which were used for this study. The manometer may be seen in Figure 3.1. Figure 3.2 views the test surface before a run.

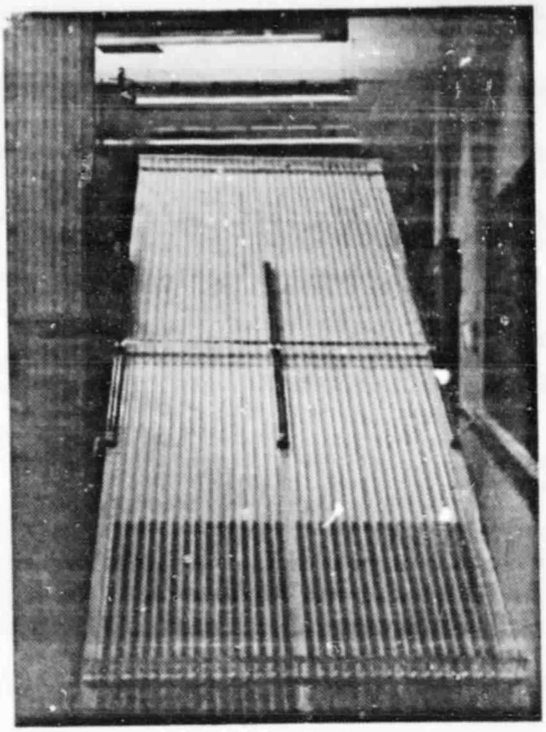


Figure 3.1 Manometer Board

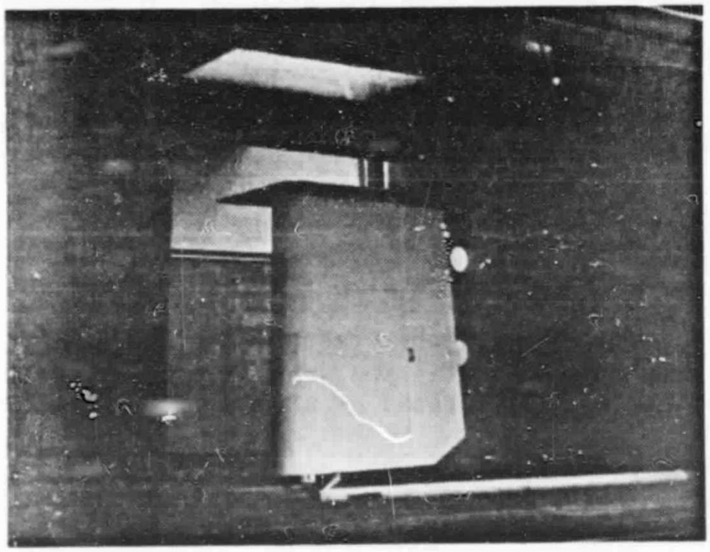


Figure 3.2 Test Surface in Wind Tunnel

3.2.2 TEST SURFACE

Provisions were made on the test surface of Figure 3.2 to measure the pressure profile at 13 different locations, on each side of the surface. All static ports were connected to the manometer board using 1/16" I.D. pressure tubing. All connections were made airtight using a polyurethane spray lacquer.

3.3 TEST SET-UP

The test set-up consisted of installing the surface in the windtunnel, and connecting the pressure lines to the appropriate connectors on the manometer board. Each pressure line was tested for blockages and leaks. When all lines were determined to be clear and airtight, the testing began. The manometer board was tilted at a 30° angle to match the inclination of the tunnel pitot-static manometer; this simplifies the data reduction.

A static pressure port was installed in the tunnel test section. The port was used for a reference static pressure on the manometer board. Corrections due to position are outlined in Subsection 3.5.1.

3.4 PROCEDURES

The procedures for the pressure profile testing followed the items of Table 3.1. A total of nine runs were performed. Each run consisted of the following steps:

1) Setting flap at desired deflection
2) Setting tunnel at desired dynamic pressure

3) Obtaining equilibrium condition in manometer board tubes

4) Setting surface at minimum angle of attack (-8°)

5) Reading manometer board pressure tubes

6) Repeating Steps (3) and (5) for angles of attack -8° to +8° by increments of 2.

Table 3.1 Pressure Profile Run Log

Run No.	α	δ_F (deg)
1	α_{SWEEP}^*	- 20
2	↓	- 15
3	↓	- 10
4	↓	- 5
5	↓	0
6	↓	+ 5
7	↓	+ 10
8	↓	+ 15
9	↓	+ 20

$^*\alpha_{SWEEP}$: -8,-6,-4,-2,0,+2,+4,+6,+8 (degrees)

Note: All testing was performed for a tunnel dynamic pressure of 25.6 psf.

3.5 DATA PROCESSING

3.5.1 DATA CORRECTIONS

The raw data obtained from the Phase I testing includes:

1) Static pressure at the 26 locations along the test surface (P_s)

2) Static pressure in the test section (P_∞)

3) Dynamic pressure at the test section (q)

These values, in centimeters of alcohol, are read from the manometer board, inclined to 30°. Before the data can be reduced, two corrections must be made. First, the dynamic pressure must also be corrected for tunnel blockage. The procedure of Pope (Reference 3) is followed. Second, the test section static pressure port (see Figure 3.3), being located forward of the test surface leading edge, reads slightly high due to the increase in dynamic pressure over the surface from tunnel blockage. The incompressible Bernoulli equation is used to calculate the true reference static pressure from the change in dynamic pressure due to blockage.

The corrections are detailed in Part II of this report, which contains all the data obtained from the pressure profile study. Included in Part II are sample calculations, computer program listings, and presentations (tabular and graphical) of the data.

3.5.2 DATA REDUCTION

Since the inclination of the manometer board (used to measure the test surface's static pressure) is identical to the dynamic pressure manometer tube, the coefficient of pressure is calculated directly from:

$$C_p = \frac{P_s - P_\infty}{q} \qquad (3.1)$$

where the pressures have been corrected as per Subsection 3.5.1. Since differential pressure is the quantity to be investigated, the difference between the lower and upper coefficients is calculated. However, the lower and upper pressure tap locations are not the same. Therefore, the lower surface pressure coefficients are linearly interpolated to the upper surface tap locations.

It is desired to find the chordwise locations that satisfy the criteria specified in Subsection 3.1.2. Toward this end, the change in pressure coefficient, $C_{p_{LOWER}} - C_{p_{UPPER}}$, is plotted against flap deflection and angle of attack for each of the 13 chordwise tap locations. (These graphs are located in Appendix A and in Part II.) This facilitates inspection and interpretation of the data. A numerical regression of the data is performed to quantify the slopes of these graphs. This augments the interpretation of the figures and is used in the theoretical analysis of Section 6.2.

3.6 RESULTS AND DISCUSSION

Based on the figures of Appendix A, tap number (13) (x/c = .766) has the best combination of linear sensitivity to flap deflection, and insensitivity to angle of attack. One pressure sensor, located here, can sense flap position with little error to angle of attack. The location of tap number (1) is best for angle of attack sensitivity, but is not used for the purpose of this study.

The required range of the sensor is best put in terms of pressure coefficient:

$$-1.2 \leq \Delta C_p \leq 1.2 \tag{3.2}$$

This is the nondimensional differential pressure occurring at the largest angle of attack and flap deflection tested. At a dynamic pressure of q = 25 psf, the required range is:

$$-30 \leq \Delta P \leq +30 \text{ psf} \tag{3.3}$$

If this study is to be repeated, it is recommended that a more common airfoil, with a known, experimental pressure distribution be used. For example, a NACA 0012 would be a good choice because of its wide use in horizontal tails.

4. PHASE II: SENSOR CALIBRATION

4.1 PURPOSE

The sensor calibration process is performed to determine the relationship between the differential pressure acting on the sensor, and its output. From this process the drive amplifier's gain value is determined.

4.2 FACILITIES AND HARDWARE

4.2.1 FACILITIES

The calibration tests were performed using the windtunnel facilities previously mentioned in Section 3.2. Also included in the facilities is the Hewlett Packard (HP) 2012 Data Acquisition System (DAS), HP9825 micro-minicomputer, and the HP9872 X-Y plotter, all shown in Figures 4.1 and 4.2. A schematic of the entire data acquisition system is illustrated in Figure 4.3.

4.2.2 HARDWARE

The hardware and components used for the calibration tests included:

1) Differential pressure sensor

2) Sensor calibration mount

3) Signal conditioner

The calibration mount is shown in Figure 4.4. The mount provides a pitot-static pressure differential across the sensor which is

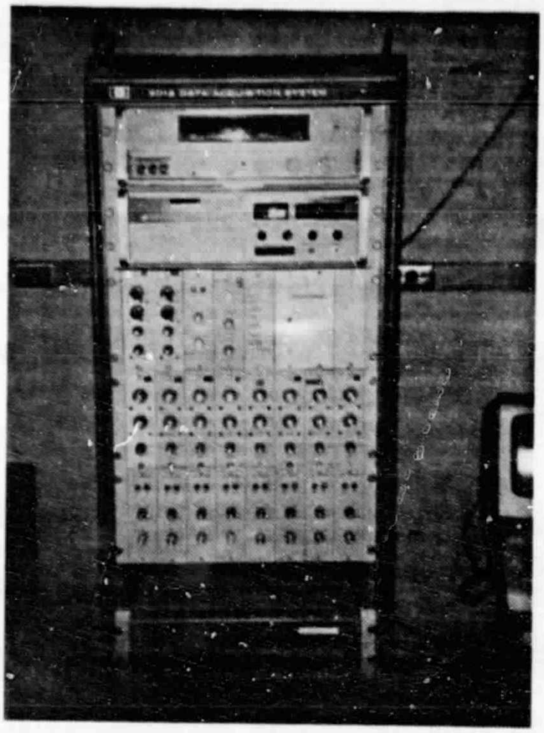


Figure 4.1 2012 Data Acquisition System

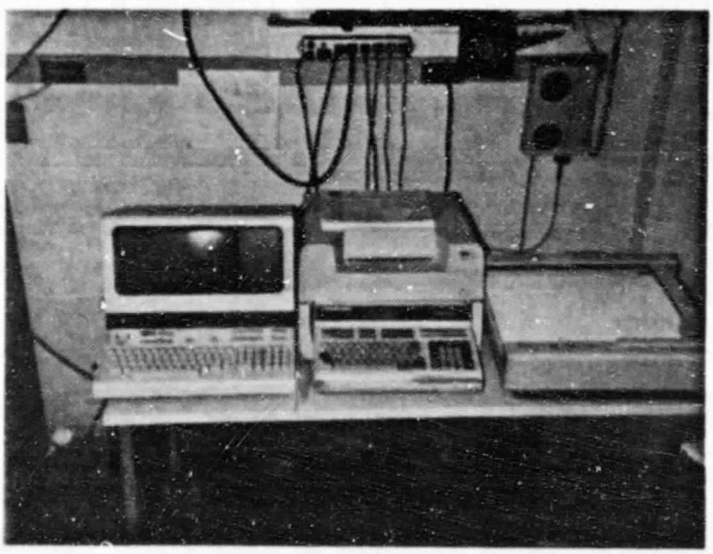


Figure 4.2 HP9825 A Computer and 9872 Plotter

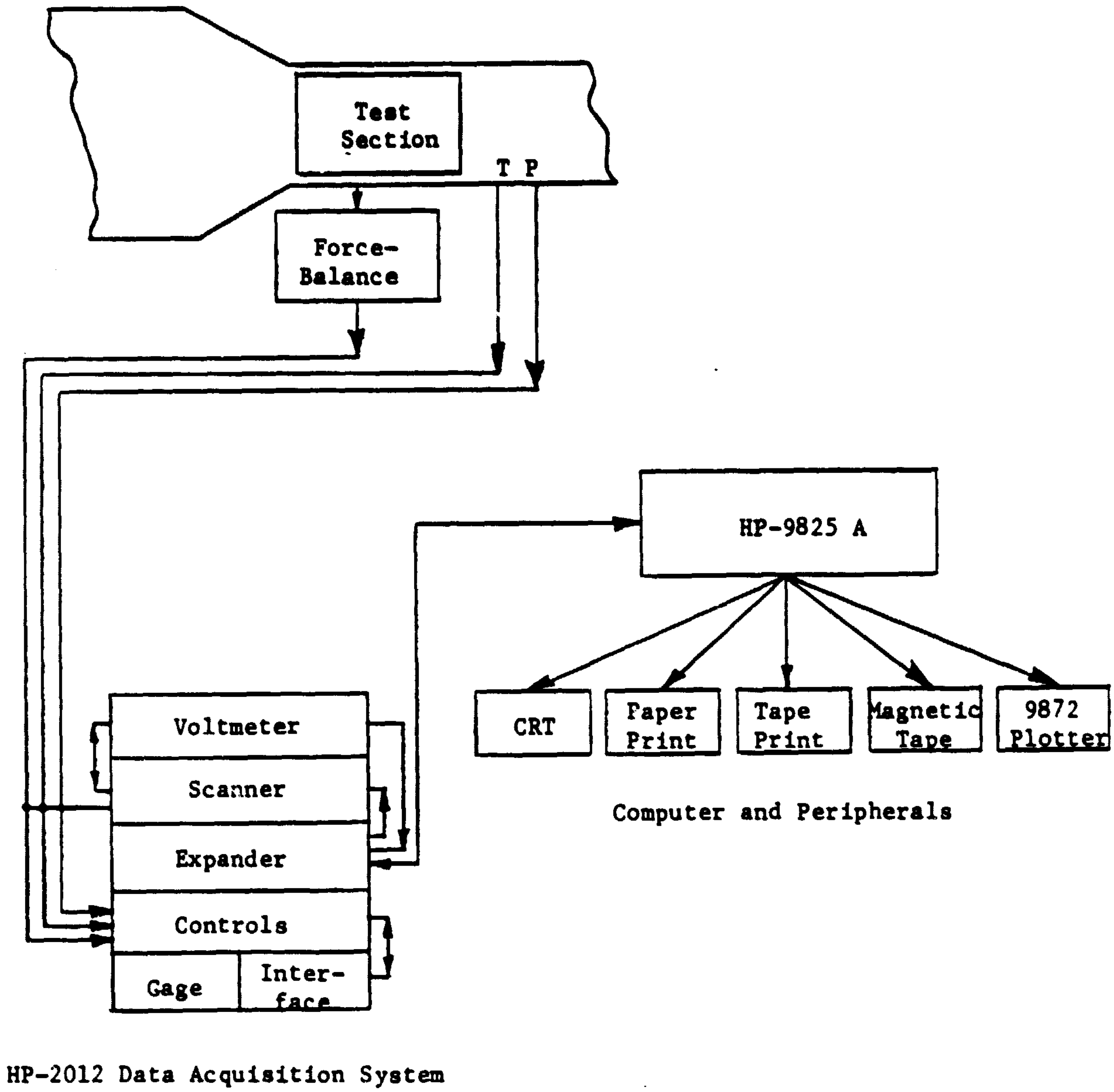


Figure 4.3 Data Acquisition System Schematic

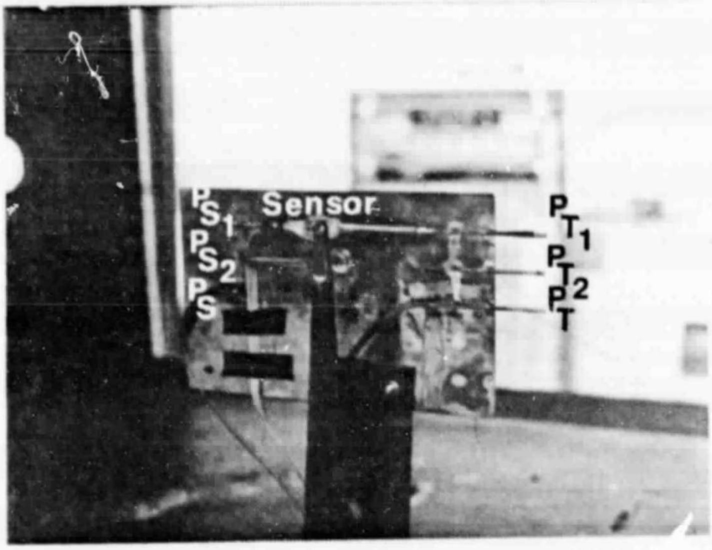


Figure 4.4 Pressure Sensor Calibration Mount

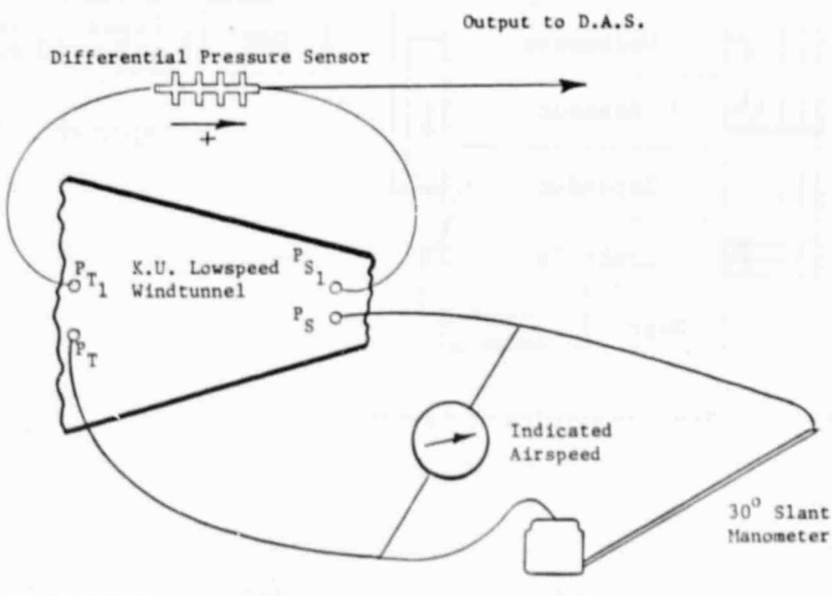


Figure 4.5 Calibration Schematic

calibrated against the tunnel manometer. The apparatus utilizes a "u" shaped windtunnel mount to secure it in the tunnel.

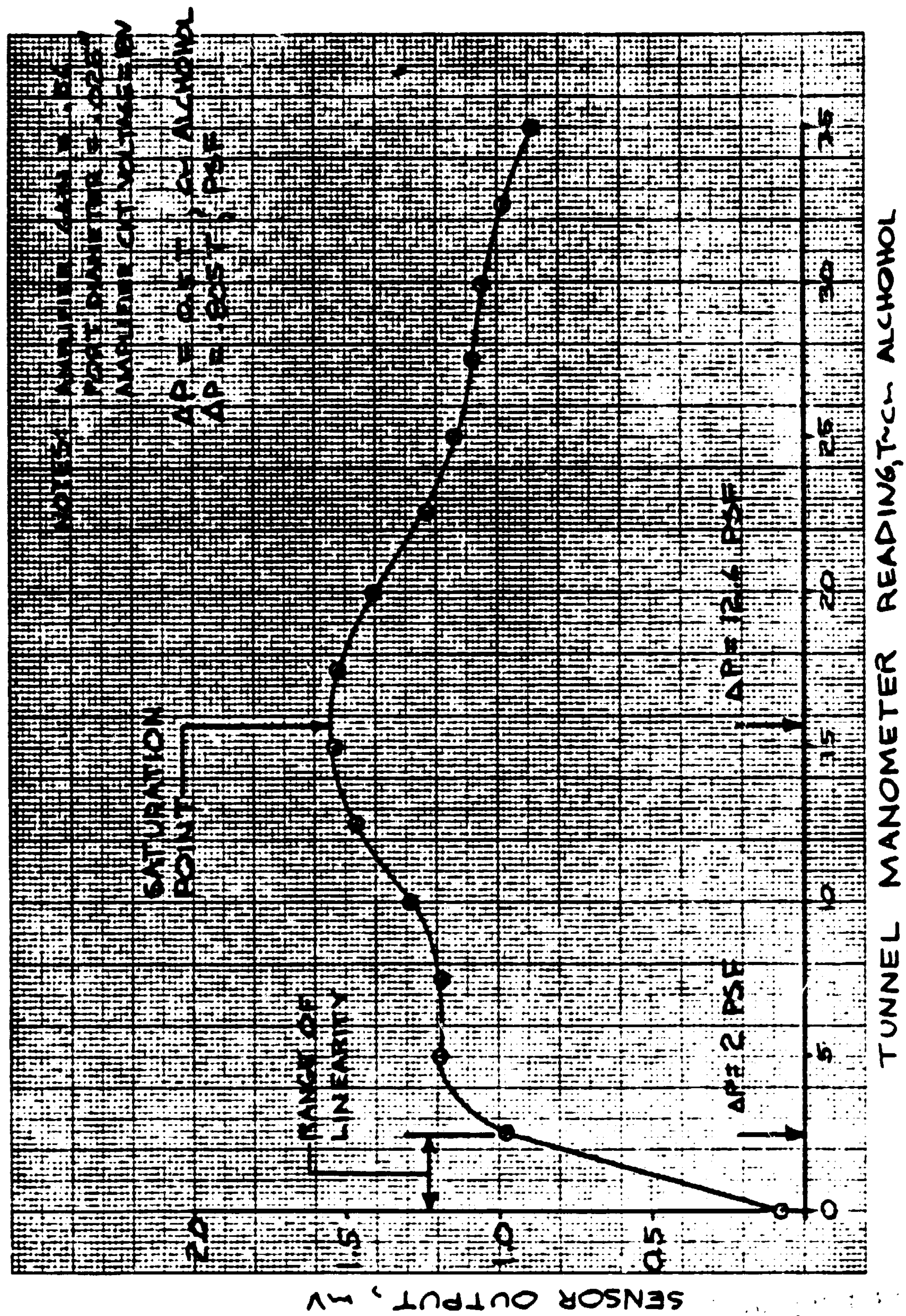
4.3 TEST SET-UP

The schematic of Figure 4.5 illustrates the uses of the components for the calibration process. The set-up consists of securing the sensor on the calibration mount and checking the side-slip angle (β) of the plate so the flow becomes just attached.

Channels 12 and 13 of the DAS are then zeroed. This is done using the 5K Ω potentiometer of Figure 2.4. In effect, this is causing the output of the fore and aft thermistors to equal, negatively. Once initialized, the calibration process can begin.

4.4 PROCEDURES

The calibration procedures follow the computer listing of Appendix B on Page 81. Once initialized, the computer asks for the tunnel dynamic pressure, which is the differential pressure of the sensor. As the desired tunnel dynamic pressure is attained, the DAS takes 10 sampled values and obtains the average. This average is then used in the output and for plotting purposes. Table 4.1 gives the output of a typical calibration run. The output is then plotted in Figure 4.6. As indicated in the output, the tunnel dynamic pressure range is from 0 to 35 cm of alcohol, or 0 to 27.2 psf.



CALC		8/18	REVISED	DATE
CHECK				
APPD				
APPD				

Figure 4.6 Sensor Calibration Curve

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Table 4.1 Calibration Run Data

Manometer Dynamic Pressure (cm. of alcohol)	Transducer Output (mVolts)
0	- 0.080
2.5	- 0.982
5.0	- 1.185
7.5	- 1.183
10.0	- 1.290
12.5	- 1.464
15.0	- 1.538
17.5	- 1.525
20.0	- 1.410
22.5	- 1.225
25.0	- 1.140
27.5	- 1.083
30.0	- 1.049
32.5	- 0.982
35.0	- 0.889

4.5 RESULTS AND DISCUSSION

The results of the calibration tests indicate that for this type of application, the sensor is not adequate due to shortcomings in two areas:

1) Sensor range

2) Dynamic response.

It was found that the sensor produced a linear output only up to approximately 2 psf. In addition, the sensor became completely saturated at values up to 13 psf. As outlined in Section 3.6, the required linear range of the sensor is ±30 psf.

A pressure sensor can usually be mathematically modelled by a pure lag. Although specific dynamic response tests were not performed, it was observed that approximately 10 seconds was

required for the sensor output to return to zero after a pressure differential was removed. This type of response is unacceptable in a feedback control system.

4.6 MODIFICATIONS AND SUBSEQUENT RESULTS

Various methods were tried to obtain different sensor characteristics. The following methods were suggested by Jim Black, designer of the sensor:

1) Change sensor port diameter
2) Change amplifier gain.

4.6.1 SENSOR PORT DIAMETER

The sensor port diameter was changed from the original diameter of .025" to a diameter of .0135". This was done by plugging both ports on the calibration mount with epoxy. The epoxy was ther drilled out to a .0135" diameter (#80 drill).

The calibration process was then repeated. It was found that while the sensor range was slightly increased, the dynamic response characterictics were degraded.

4.6.2 AMPLIFIER GAIN

The amplifier (sensor) was altered by changing the resistance of the input resistor to the amplifier of Figure 2.4. The amplifier gain was changed to values of .01, .10, and .50. Again, the saturation point remained unchanged.

4.6.3 AMPLIFIER VOLTAGE

The sensor circuit of Figure 2.4 defines the input voltage to the amplifier as +22 volts d.c. The amplifier voltage used in the testing was set at 15 volts d.c. To see if any difference would result, the voltage was increased to 18 volts d.c. (the limit voltage for the LM 324N OP AMP). This tended to increase the saturation point, but still not to the required value. The linear range appeared to be unchanged.

4.6.4 MIDDLE THERMISTOR

A sensor thermistor profile was conducted to determine how the voltage, current, and resistance of each thermistor in the sensor was changing as the pressure differential increased. It was concluded that the middle thermistor was not able to increase its power output after a relatively low pressure was applied to the sensor. Four (4) different thermistors replaced the middle thermistor to check this theory. Using values of 5K, 10K, 50K, and 100K Ω, the power output of the middle thermistor was increased. The results were encouraging but still saturated out before maximum estimated pressure differential occurred.

4.7 CONCLUSIONS AND RECOMMENDATIONS

The sensor is not suitable for the purpose of this study. There are two types of pressure sensors available today that meet the needs of the project.

Conventional diaphragm pressure sensors have the range, accuracy, and dynamic response required but are relatively expensive.

A Piezoresistive sensor offers the same qualities for a reasonable cost. A brief literature search is recommended before final selection is made.

5. PHASE III: FREQUENCY RESPONSE

Phase III of this study is designed to determine the transfer function for the system, actuator, and sensor. The circuit can be either assumed to be a pure gain, or determined analytically. Once these transfer functions are known, a closed loop analysis of a typical feedback control system can be performed, and the stability determined. A theoretical analysis of a typical control system is included in Section 6.2.

Phase III is composed of Parts A, B, and C. The objective of Part A is to obtain standard lift, drag, and pitching moment coefficients and their variations with α and δ_F. The run schedule for Part A is given in Table 5.1.

Table 5.1 Part A Run Schedule

Run No.	α	δ_F (degrees)	q (psf)
1	1	- 20	25
2	↓	- 15	↓
3	↓	- 10	↓
4	↓	- 5	↓
5	↓	0	↓
6	↓	+ 5	↓
7	↓	+ 10	↓
8	↓	+ 15	↓
9	↓	+ 20	↓

Note: 1 α = -8,-6,-4,-2,0,+2,+4,+6,+8 (degrees)

Part B of Phase III is designed to obtain preliminary data on system performance at various angles of attack and initial flap positions. (Several of the runs may be deleted if the initial

indications are promising.) This is accomplished by applying a step input to the pressure sensor via the signal conditioner control box. The run schedule for Part B is given in Table 5.2.

Table 5.2 Part B Run Schedule

Run No.	α (deg)	$\Delta P_{COMMAND}$*	$\delta_{F_{INITIAL}}$ (deg)	q (psf)
1	- 8	2	- 10	25
2	- 8	↓	0	↓
3	- 4	↓	- 10	↓
4	- 4	↓	0	↓
5	0	↓	- 10	↓
6	0	↓	0	↓
7	+ 4	↓	- 10	↓
8	+ 4	↓	0	↓
9	+ 8	↓	- 10	↓
10	+ 8	↓	0	↓

Note: 2 ΔC_p = 0.1,0.3,0.5,1.0 or

ΔP = 2.5,7.5,12.5,25 psf at q = 25psf

The data obtained will be presented as illustrated in Figure 5.1.

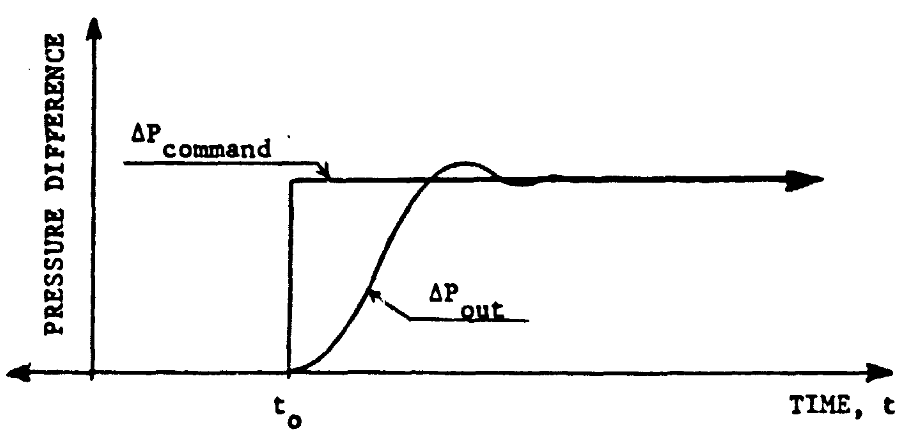

Figure 5.1 Response to a Step Input

Part C will be used to determine the necessary frequency response characteristics of the system. A total of 18 windtunnel runs will be used to obtain the data, each containing the following:

INPUTS	OUTPUTS
$\delta_{F_{IN}}(t) = \lvert\delta_{F_{IN}}\rvert \cos\omega t$	$\delta_{F_{OUT}}(t) = \lvert\delta_{F_{OUT}}\rvert \cos(\omega t + \phi_1)$
	$\Delta P_{OUT}(t) = \lvert\Delta P_{OUT}\rvert \cos(\omega t + \phi_2)$
$\Delta P_{IN}(t) = \lvert\Delta P_{IN}\rvert \cos\omega t$	$\delta_{F_{OUT}}(t) = \lvert\delta_{F_{OUT}}\rvert \cos(\omega t + \phi_3)$
	$\Delta P_{OUT}(t) = \lvert\Delta P_{OUT}\rvert \cos(\omega t + \phi_4)$

The reader should note the following:

1) δ_F inputs directly into the actuator.

2) ΔP inputs into the control circuit.

3) Frequency range: $.01 < \omega < 1000$ rad/sec.

Tables 5.3 (a) and (b) give the run schedules for this part of the frequency response testing. The sinusoidal inputs to the actuator and sensor will be accomplished by connecting a function generator to the appropriate inputs on the signal conditioner. A two-channel strip chart recorder will be used to monitor the outputs of the sensor and L.V.D.T.

The data obtained during this phase of the study would be presented in the form of a standard bode plot. It will be from these plots that a transfer function will be derived. These transfer functions will then be tested against those used in the theoretical analysis of Section 6.2.

Table 5.3(a) Frequency Response Test Runs - Position

Run No.	α (deg)	$\lvert \delta_{F_{IN}} \rvert$	$\lvert \Delta P_{IN} \rvert$	q (psf)
1	-8°	3	-	25
2	-6		-	
3	-4		-	
4	-2		-	
5	0		-	
6	$+2$		-	
7	$+4$		-	
8	$+6$		-	
9	$+8$		-	

Table 5.3(b) Frequency Response Test Runs - Pressure

Run No.	α (deg)	$\lvert \delta_{F_{IN}} \rvert$	$\lvert \Delta P_{IN} \rvert$	q (psf)
1	-8	-	2	25
2	-6	-		
3	-4	-		
4	-2	-		
5	0	-		
6	$+2$	-		
7	$+4$	-		
8	$+6$	-		
9	$+8$	-		

Note: 2 $\lvert \Delta P_{IN} \rvert$ = 2.5,7.5,12.5,25 psf at q = 25 psf

3 $\lvert \delta_{F_{IN}} \rvert$ = 5,10,15,20 degrees

6. THEORETICAL ANALYSIS

6.1 THEORETICAL PRESSURE DISTRIBUTION

The windtunnel test described in Chapter 3 required significant amounts of time, manpower, and hardware development. It is desirable to find a way to bypass the need for this test. If a commonly used airfoil with the necessary testing already performed (e.g., NACA 4 and 5 digit airfoils) is chosen, then the published results can be used instead of repeating the test. However, the test surface employed for this study incorporated a unique airfoil (see Figure 6.1) with an unknown pressure distribution. Therefore, to avoid windtunnel testing, numerical methods must be used. The method used for this study was the NASA/Langley Single Element Airfoil Program (SEAP), which was stored on the University of Kansas Honeywell 66/60.

The program requires, as input, the airfoil coordinates listed in Table 6.1. Mach number and Reynolds number inputs are the same as in the Phase I testing. Included in the output is a listing of the pressure coefficients at chordwise stations along the airfoil (see Appendix B for sample output).

A total of 16 cases were input to the program—four angles of attack ($\alpha = 0, 3, 6, 9°$) and four flap deflections ($\delta_F = 0, 5, 10, 15°$). It is assumed that symmetry holds with respect to angle of attack and flap deflections. Flap deflections are input to the program by altering the airfoil coordinates aft of the hingeline (see Figure 6.2 and Table 6.2). Due to difficulties with software, results were not obtained for the case of $\alpha = 9°$, $\delta_F = 0°$.

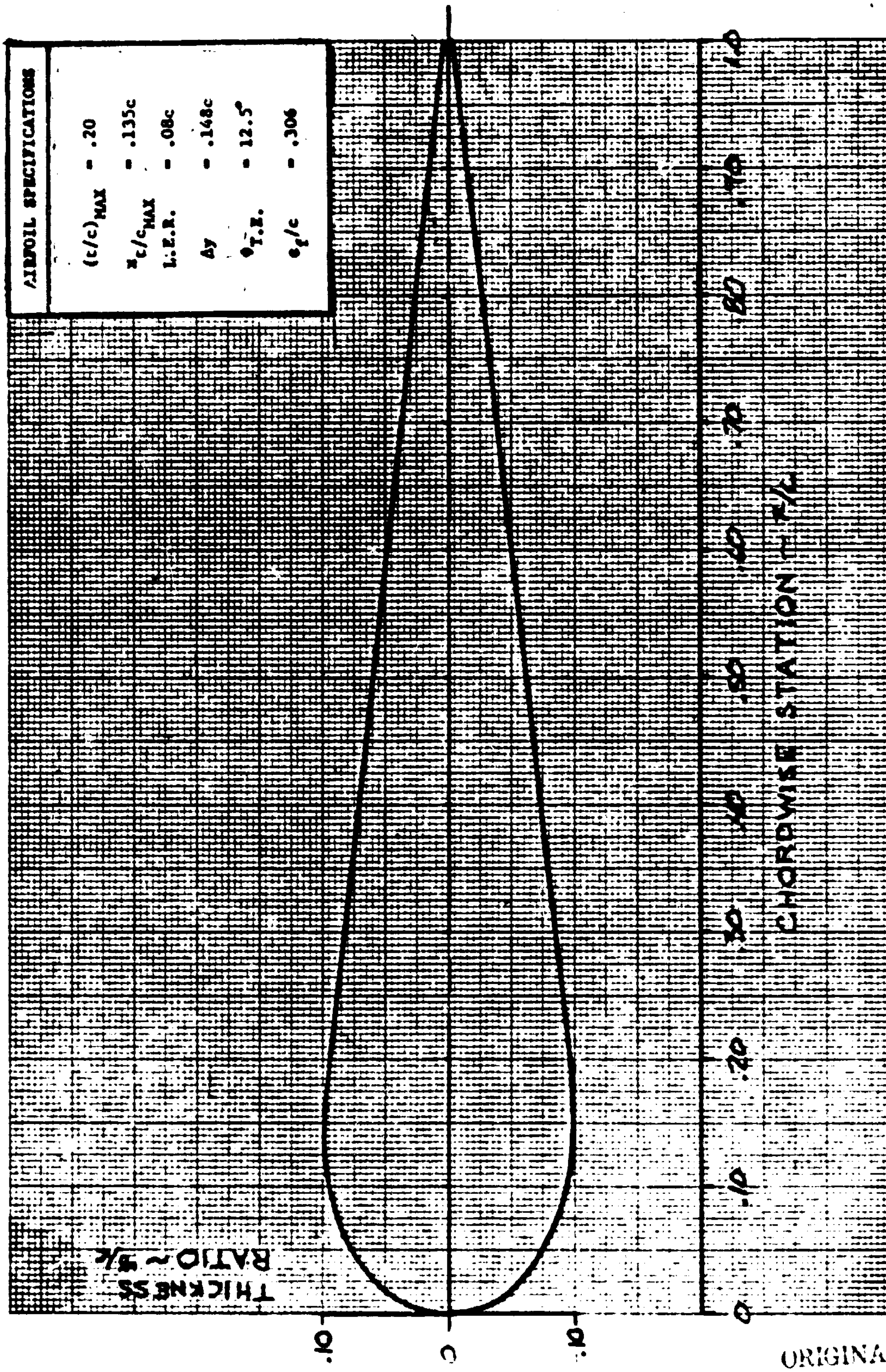

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Figure 6.1 Delta P Airfoil Section

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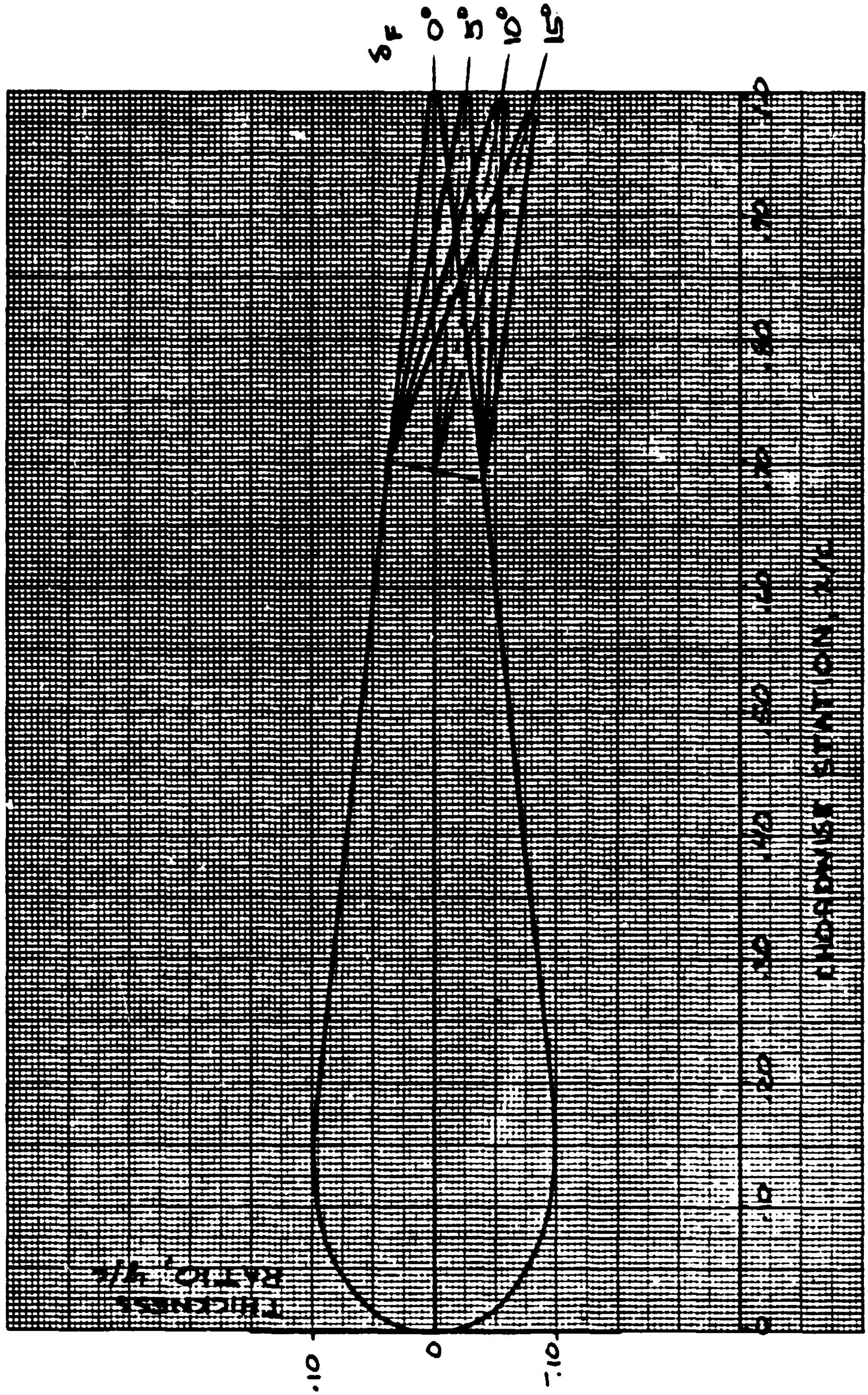

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Figure 6.2 Airfoil with Flap Deflections

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Table 6.1 Delta P Airfoil Coordinates - Zero Flap Deflection

XU (=XL)	ZU (= -ZL)	XU (=XL)	ZU (= -ZL)
0	0	.325	.080
.00625	.032	.350	.077
.0125	.043	.375	.074
.01875	.052	.400	.071
.0250	.057	.425	.06825
.03125	.064	.450	.0655
.0375	.069	.475	.06275
.04375	.073	.500	.060
.0500	.077	.525	.05725
.05625	.081	.550	.0545
.0625	.083	.575	.05175
.06875	.085	.600	.049
.0750	.087	.625	.04625
.08125	.090	.650	.0435
.0875	.092	.675	.04075
.09375	.093	.700	.038
.100	.094	.725	.035
.1125	.0965	.750	.032
.125	.098	.775	.029
.1375	.100	.800	.026
.150	.099	.825	.02325
.1625	.0985	.858	.0205
.175	.097	.875	.01775
.1875	.096	.900	.015
.200	.095	.925	.01225
.225	.092	.950	.0095
.250	.089	.975	.00675
.275	.086	1.000	.004
.300	.083		

Table 6.2 Delta P Airfoil Coordinates - Flap Deflection = 5, 10, 15 (degrees)

Substitute into Table 6.1 for $.70 \leq XU \leq 1.00$

XU (=XL)	$\delta_F = 5^\circ$		$\delta_F = 10^\circ$		$\delta_F = 15^\circ$ *	
	ZU	ZL	ZU	ZL	ZU	ZL
.700	.038	-.040	.038	-.041	.037	-.043
.725	.032	-.039	.0305	-.0425	-	-
.750	.027	-.038	.023	-.044	.017	-.050
.775	.022	-.037	.0155	-.0455	-	-
.800	.017	-.036	.008	-.047	-.003	-.057
.825	.012	-.0355	.0005	-.0485	-	-
.850	.007	-.035	-.007	-.050	-.023	-.064
.875	.002	-.034	-.0145	-.051	-	-
.900	-.003	-.033	-.022	-.052	-.043	-.071
.925	-.008	-.032	-.0295	-.0535	-	-
.950	-.013	-.031	-.037	-.055	-.063	-.078
.975	-.018	-.030	-.0445	-.0565	-	-
1.000	-.023	-.029	-.052	-.058	-.083	-.083

* For the $\delta_F = 15^\circ$ case, it was necessary to input a slightly fewer number of coordinates. Since the aft portion of the surface is essentially flat, this is considered to make little, if any, difference.

The C_p values generated are at distributed points (chosen by the computer) along the airfoil. Consequently, for comparison with the windtunnel data, the pressure coefficients are interpolated to the 13 chordwise locations of the test surface. Then the same data reduction process outlined in Subsection 3.5.2 is performed on the data. The results are tabulated and plotted in Appendix C.

From Figures C.1 through C.26 it is seen that the general sensitivity trends follow those of the windtunnel data. However, contrary to the experimental data, the pressure differential, at all locations, is sensitive to flap deflection. In addition, the results are somewhat nonlinear--especially at the five degree flap deflection case. The maximum C_p predicted by the SEAP at $x/c = .766$ agrees reasonably well with the experimental data, but this is not the case at the forward tap locations.

There are a few explanations for the discrepancies between the experimental and theoretical data. First, the large thickness ratio (t/c) and extreme forward location of the maximum t/c might not lend itself to accurate analysis by the SEAP. Second, since the program is not specifically designed to handle flap deflections, the method of doing so could lead to errors. Finally, the program utilizes a two-dimensional analysis technique,while the windtunnel test is three dimensional.

While the results of the theoretical analysis do not correlate exactly with the experimental data, they are promising enough to prompt further study. Analysis of other airfoils, perhaps with another computer program more suited to the specific needs of the project, is recommended before discounting the theoretical approach.

6.2 CLOSED LOOP DYNAMIC STABILITY ANALYSIS

A study has been performed to see what the closed loop performance of a system is (or should be) that incorporates differential pressure command as opposed to elevator position command. In analyzing the system, the block diagram of Figure 6.3 is used. The system illustrated is a pitch attitude hold loop which uses pressure as the feedback quantity in the $\delta_{E_{COMMAND}}$ inner loop. As a control a conventional pitch attitude hold system which incorporates elevator position command (of Figure 6.4) was also analyzed.

For simplification, the amplifier of the inner loop has been assumed to be a pure gain, equal to unity:

$$K_{AMP} = 1 \tag{6.1}$$

The elevator servo is assumed to be a first order lag:

$$\frac{\delta_E(s)}{\delta_{E_{OUT}}(s)} = \frac{10}{s + 10} \tag{6.2}$$

The break frequency of 10 rad/sec is representative of a reasonably fast, general aviation actuator.

The sensor calibration constant, or position command gain, is a function of dynamic pressure and is obtained from the numerical regression of Chapter 10, Part II, of this report:

$$\frac{\partial \Delta C_P}{\partial \delta_F} = .047 \tag{6.3}$$

or:

$$\frac{\partial \Delta P}{\partial \delta_F} = K_{\substack{SENSOR \\ \& \ CIRCUIT}} = .047q \tag{6.4}$$

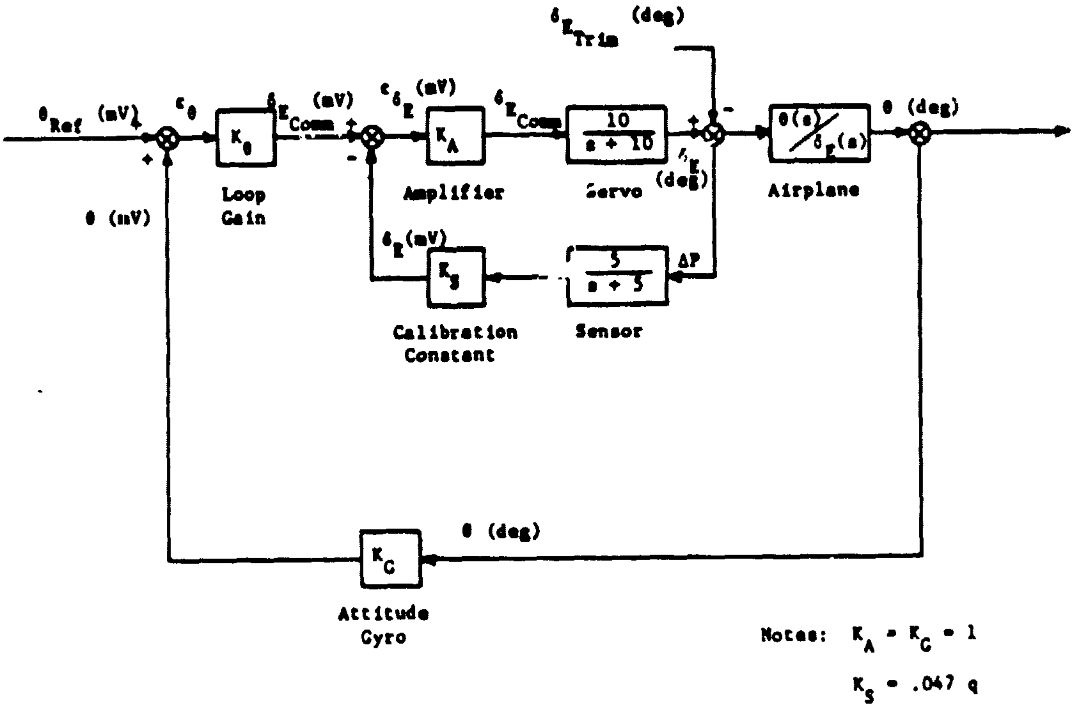

Figure 6.3 System Block Diagram (Pressure Command)

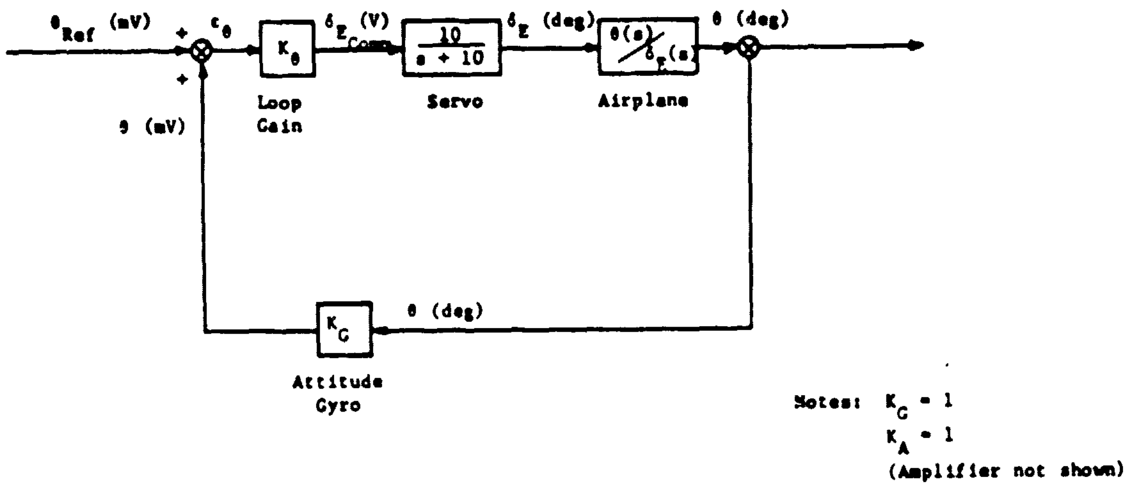

Figure 6.4 System Block Diagram (Position Command)

The aerodynamic lag* and the sensor lag are combined into one first order transfer function:

$$\frac{\delta_{E_{IN}}(s)}{\Delta P_{OUT}(s)} = \frac{a}{s + a} = \frac{5}{s + 5} \tag{6.5}$$

The break frequency of 5 rad/sec has been assumed as "reasonable." The experimental determination of this lag is one of the major purposes of the Phase III windtunnel test.

The airplane $\frac{\theta(s)}{\delta_E(s)}$ transfer function is derived using data obtained from Appendix B of Reference 4 for a typical general aviation airplane. To investigate the effect of dynamic pressure on system performance, high and low values were used:

Case 1: $q = 8.47$ psf ($K_s = .40$)

Case 2: $q = 76.28$ psf ($K_s = 3.59$)

Using Reference 5 in conjunction with the University of Kansas Aerospace Engineering Departmen's HP9825A micro-minicomputer, the airplane $\frac{\theta(s)}{\delta_E(s)}$ transfer function was derived for each case; and the root loci of Figures 6.5 through 6.8 were generated. The computer output used to construct the root loci is located in Appendix D. Notice that with the inner loop pressure command, the sensor and actuator combine to form an oscillatory pair. In fact, Figure 6.6 shows that it is these poles which go unstable at high dynamic pressure.

It can be seen from the figures that a loop gain equal to

$$K_\theta = 1.0 \tag{6.6}$$

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* The aerodynamic lag represents the lag between a change in δ_E and the resulting pressure change at the sensor.

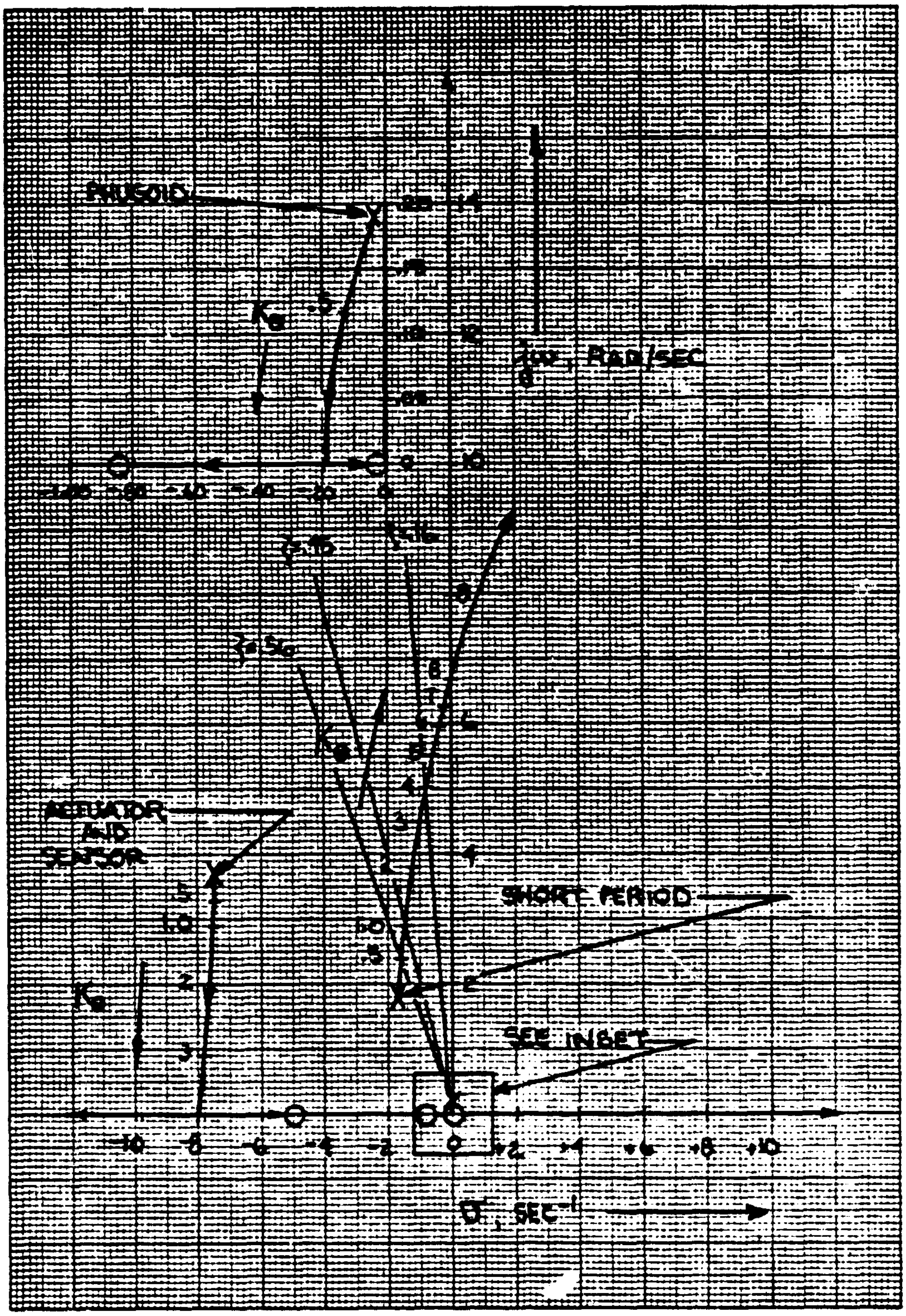

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Figure 6.5 Pitch Attitude Hold for Airplane A (App. C, Ref 4) with Pressure Sensor (q= 8.5 psf)

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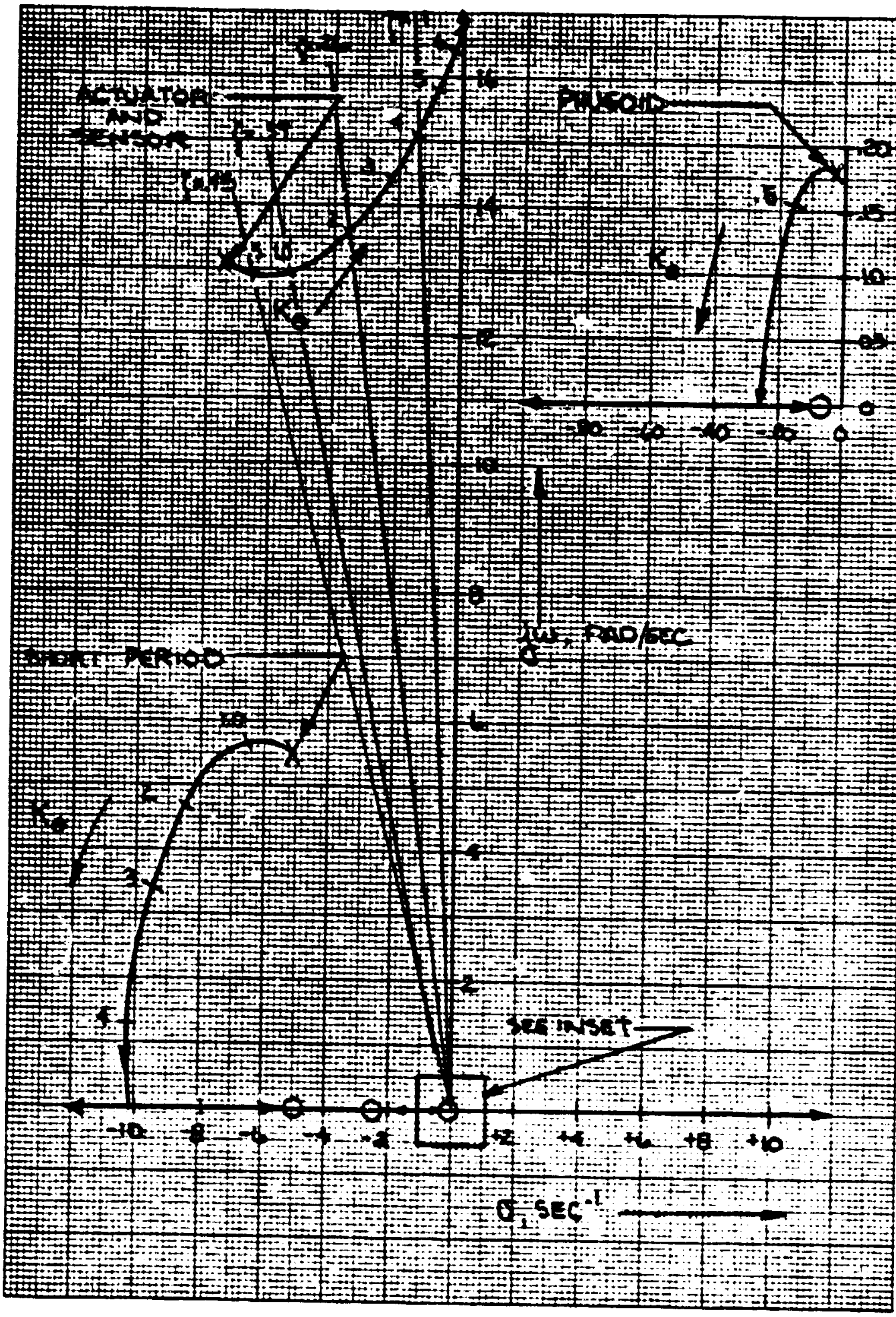

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Figure 6.6 Pitch Attitude Hold for Airplane A (App. C, Ref 4) with Pressure Sensor (q= 76.3 psf)

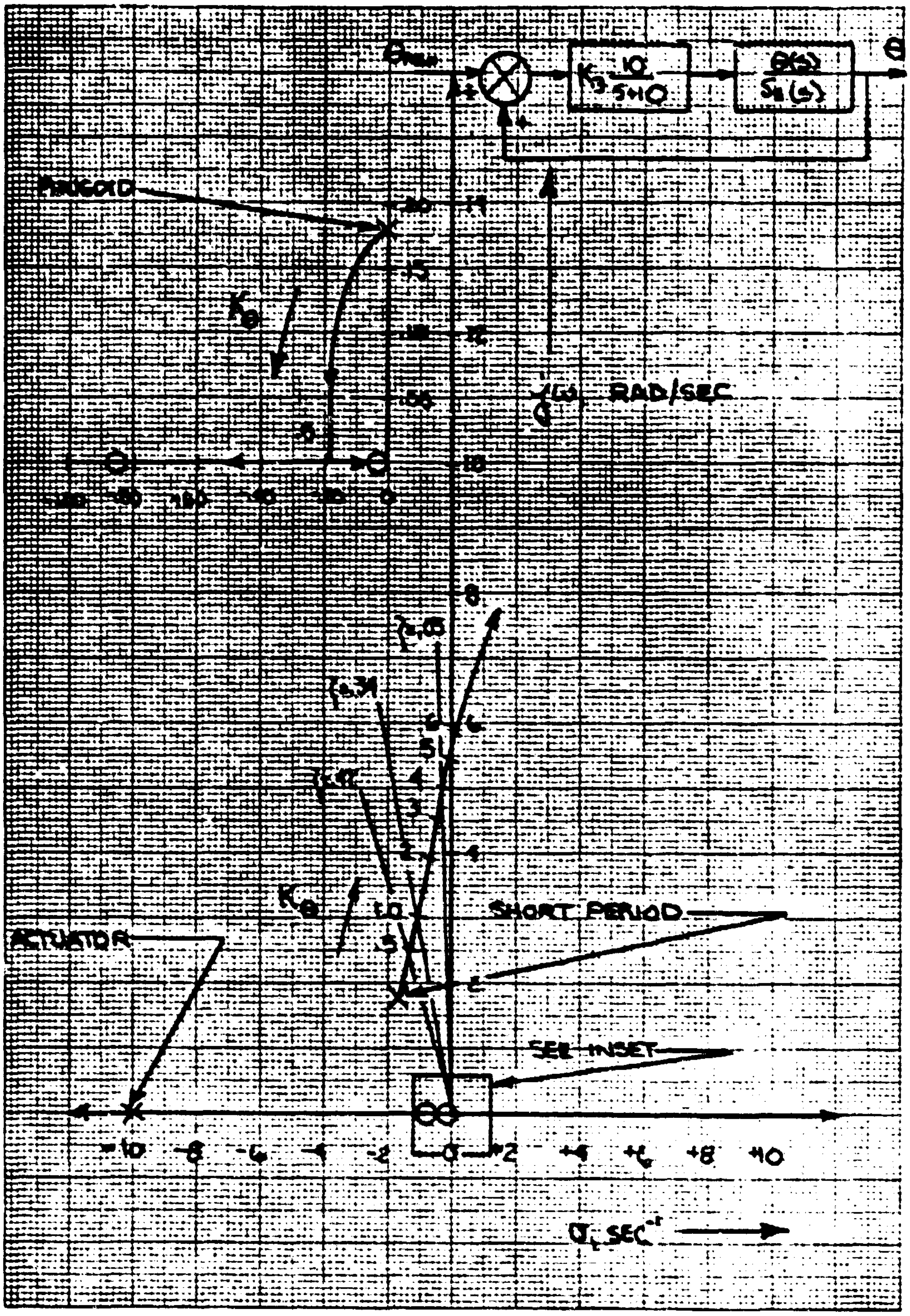

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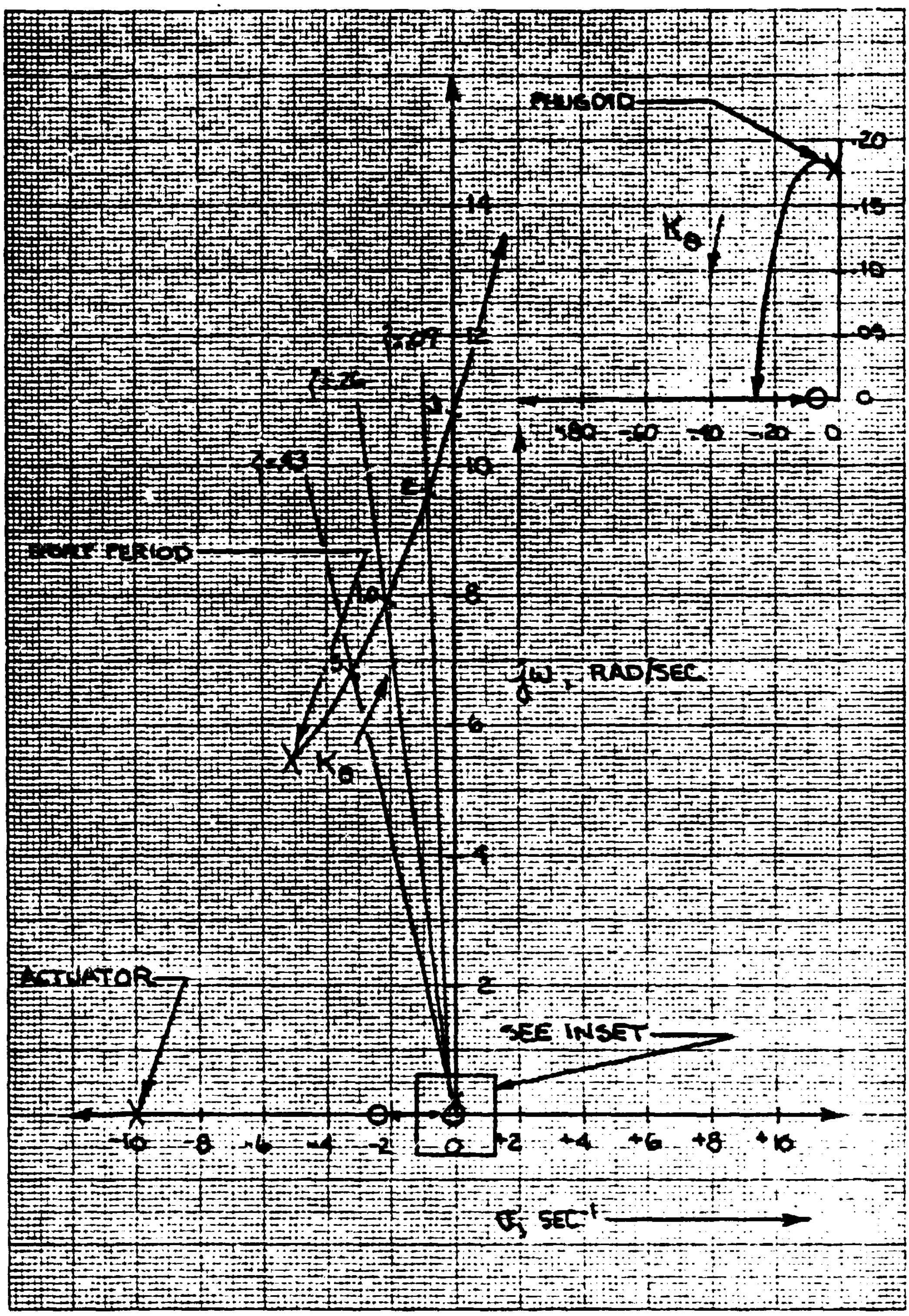
Figure 6.7 Pitch Attitude Hold for Airplane A (App. C, Ref 4) (q= 8.5 psf)



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yields reasonable damping ratios and natural frequencies for the pressure sensor pitch attitude hold system. It is also observed that in the system with the pressure sensor, the gain margin remains relatively constant with dynamic pressure as compared to the conventional system. It appears that gain scheduling with dynamic pressure can be avoided without a compensator or inner loop pitch damping.

Again it should be noted that the sensor properties have not been determined. The frequency response data obtained during Phase III will yield the necessary information for a more detailed study. This analysis is merely a preliminary investigation of the closed loop characteristics of the pressure feedback system.

7. CONCLUSIONS AND RECOMMENDATIONS

The sensor used in this study does not have the qualities required to determine the feasibility of differential pressure feedback in a flight control system. Of available sensors, the piezoresistive has the characteristics most suited for this type of application.

Once this concept has been proven feasible, a follow-up program is recommended which will include the use of a more conventional airfoil. Within this program, both theoretical and experimental pressure distributions should be investigated.

8. REFERENCES

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2. Daugherty, D. G.; A Critical Review of an Automatic Attitude Command Control System Electronics Design; Flight Research Laboratory Report FRL 325, The University cf Kansas, Lawrence, Kansas, November 1974.

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5. Clarke, Robert; A Computer Program for Determining Open and Closed Loop Dynamics of Airplanes; The University of Kansas, Lawrence, Kansas, May 1980.

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APPENDIX A

PRESSURE PROFILE SENSITIVITY PLOTS

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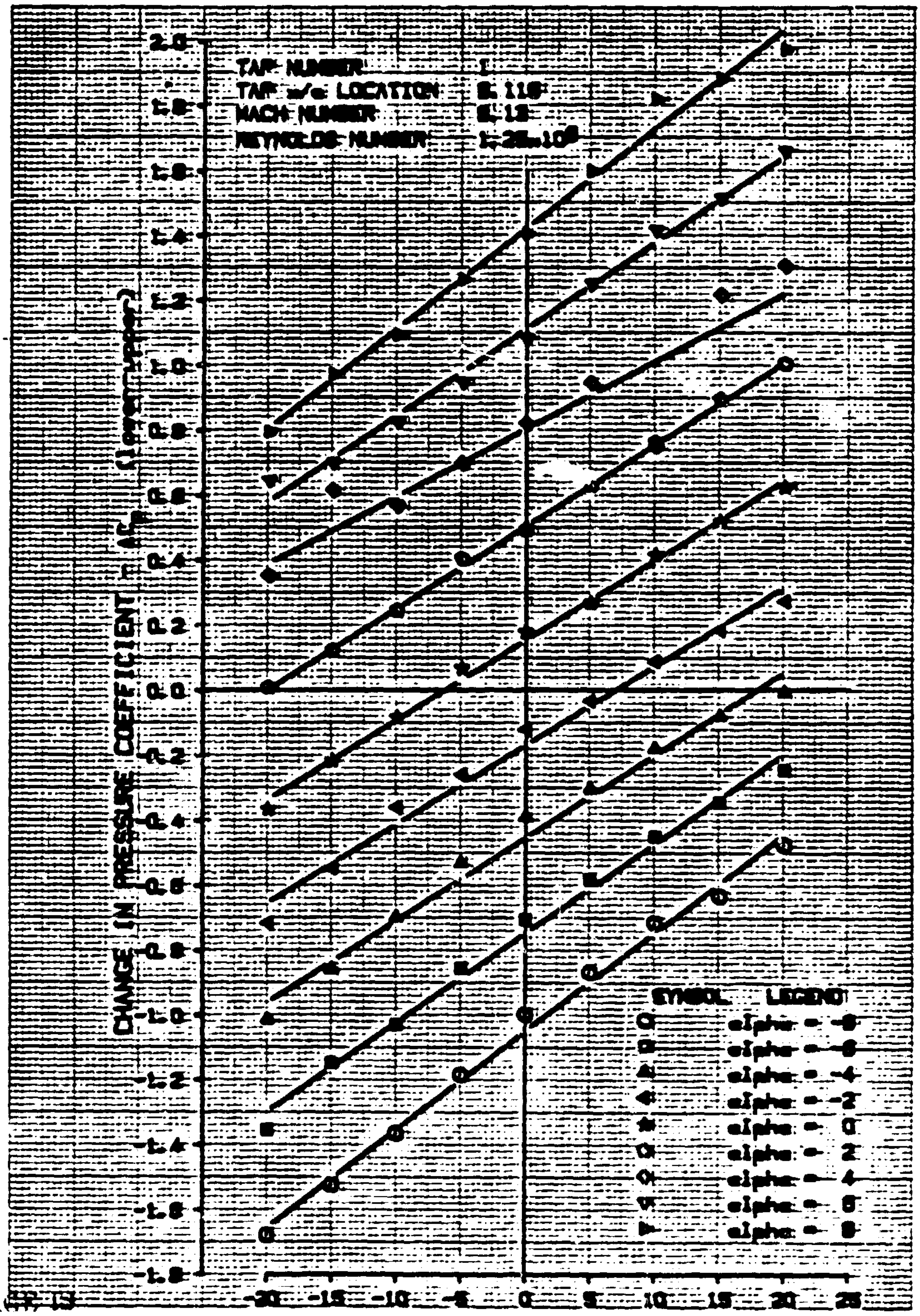
A.1 FLAP DEFLECTION

NOTE: LOWER SURFACE C_p INTERPOLATED TO UPPER SURFACE TAP LOCATION



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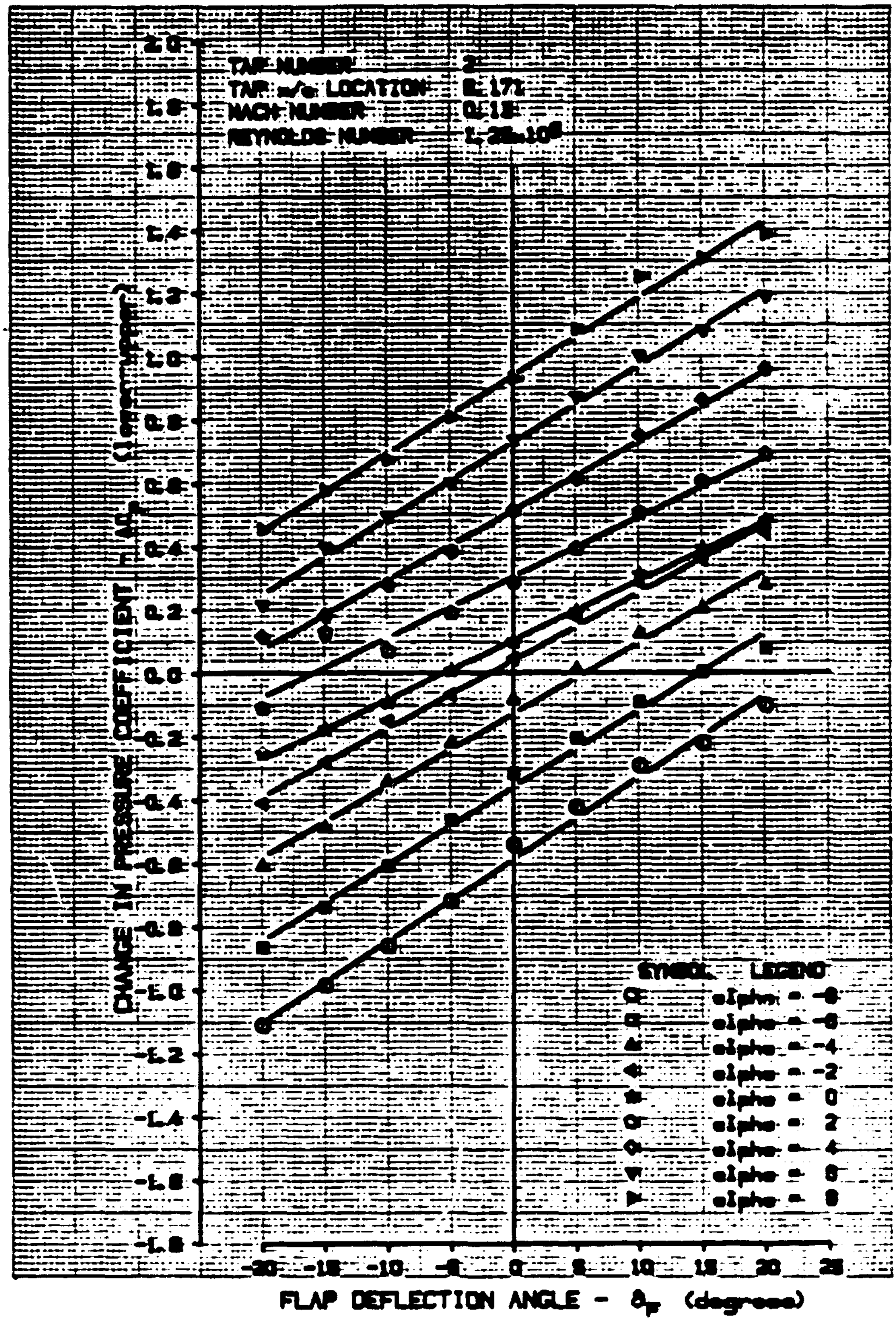
NOTE: LOWER SURFACE C_p INTERPOLATED TO UPPER SURFACE TAP LOCATION



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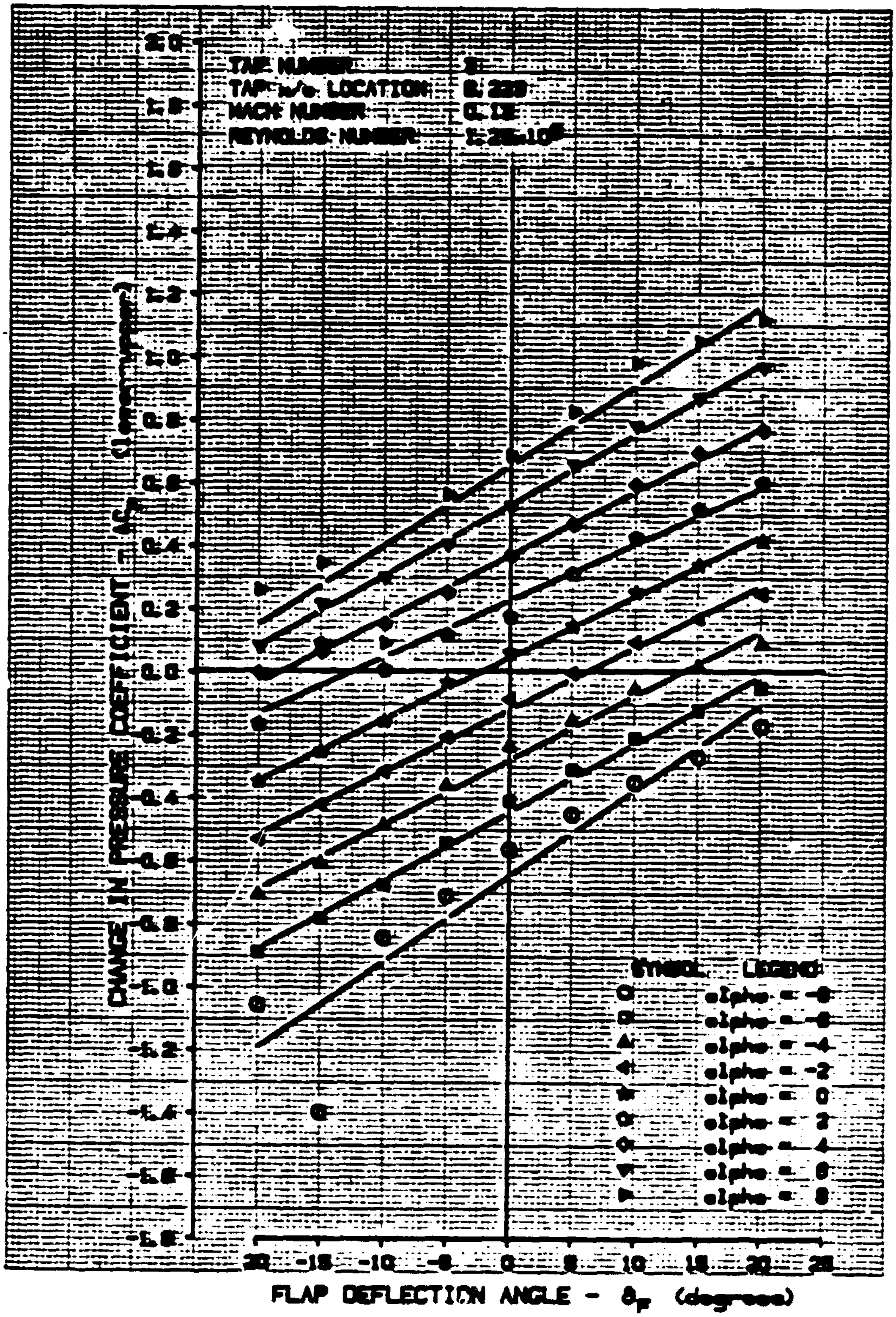
NOTE: LOWER SURFACE C_p INTERPOLATED TO UPPER SURFACE TAP LOCATION



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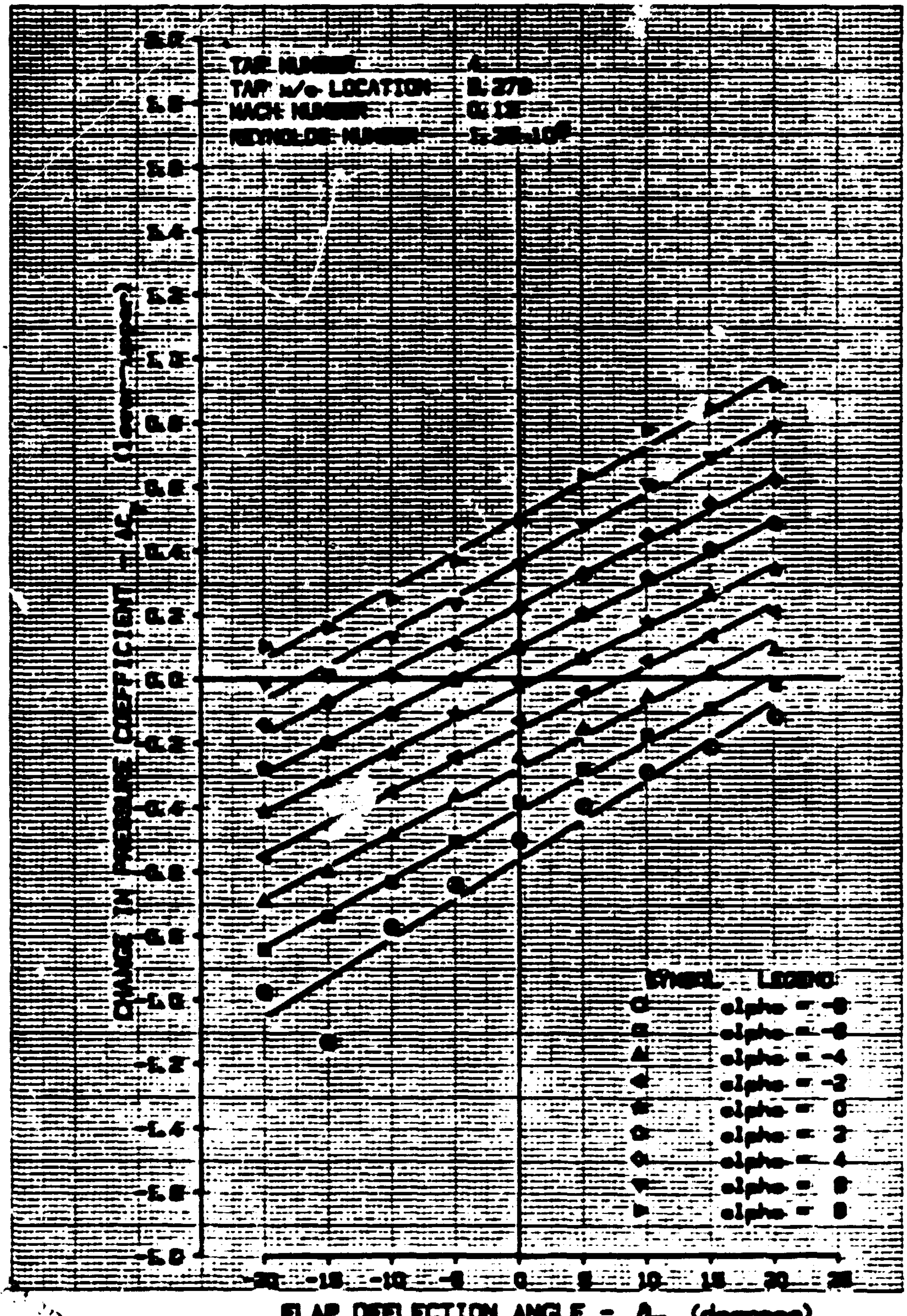
NOTE: LOWER SURFACE C_p INTERPOLATED TO UPPER SURFACE TAP LOCATION



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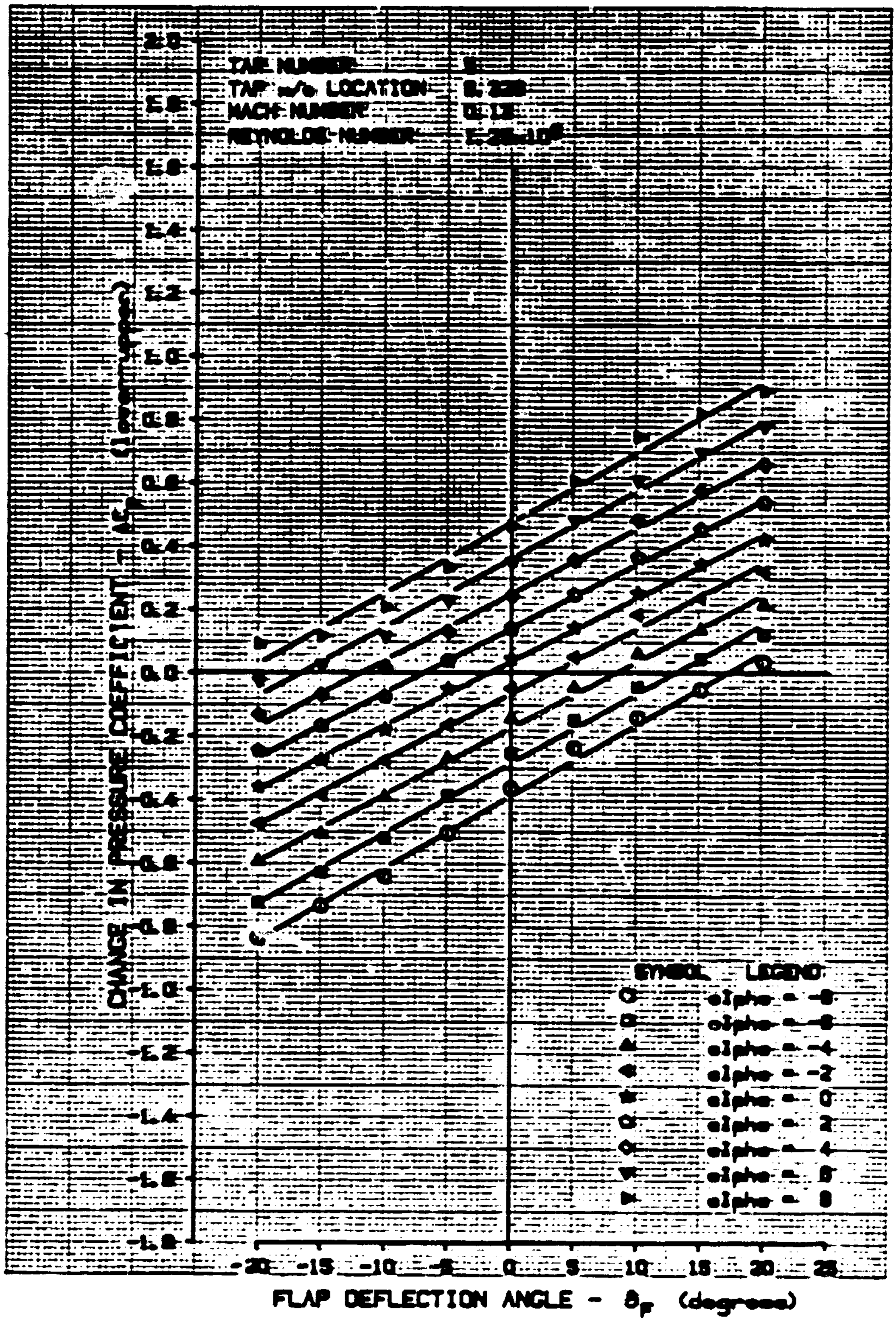
NOTE: LOWER SURFACE C_p INTERPOLATED TO UPPER SURFACE TAP LOCATION



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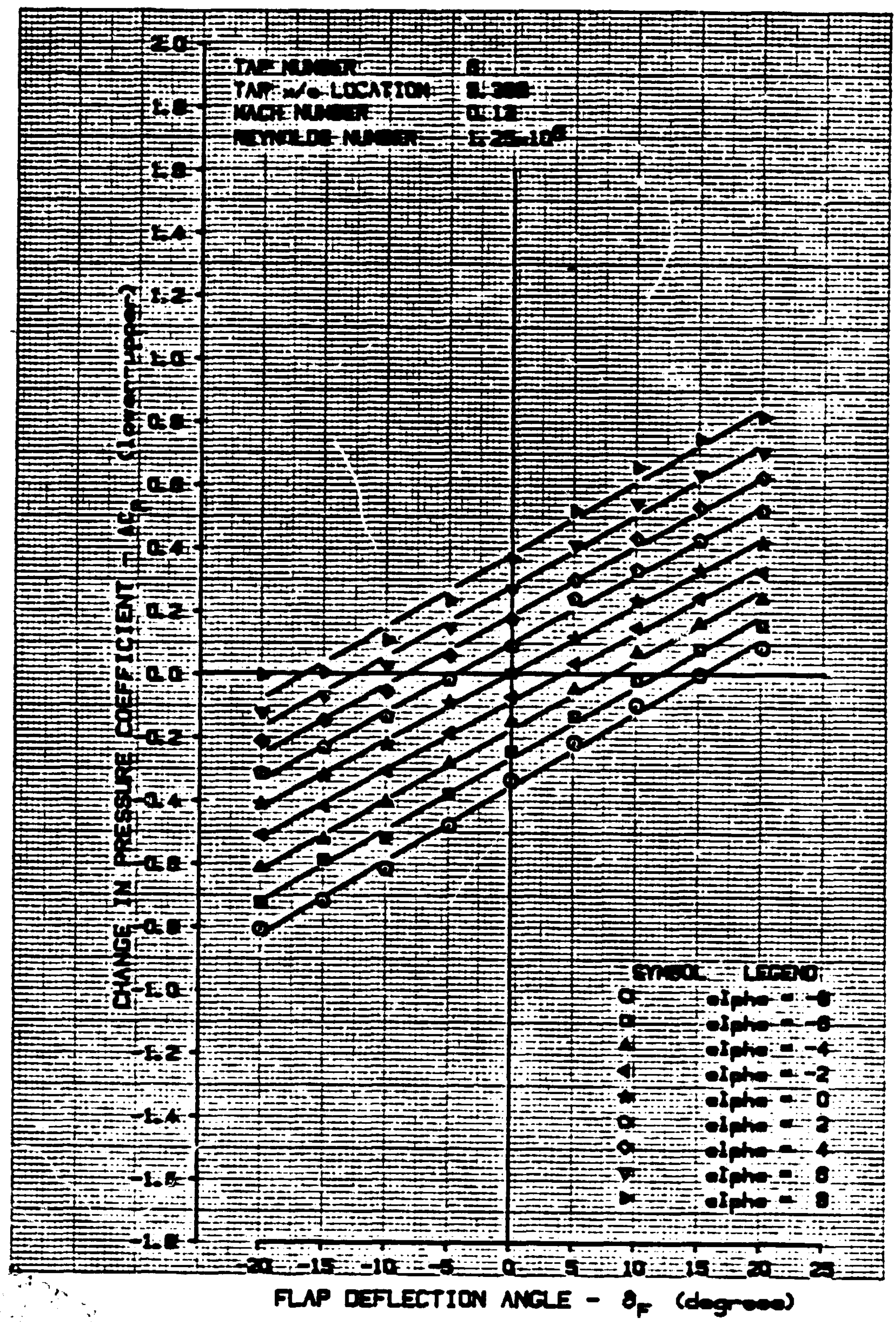
NOTE: LOWER SURFACE C_p INTERPOLATED TO UPPER SURFACE TAP LOCATION



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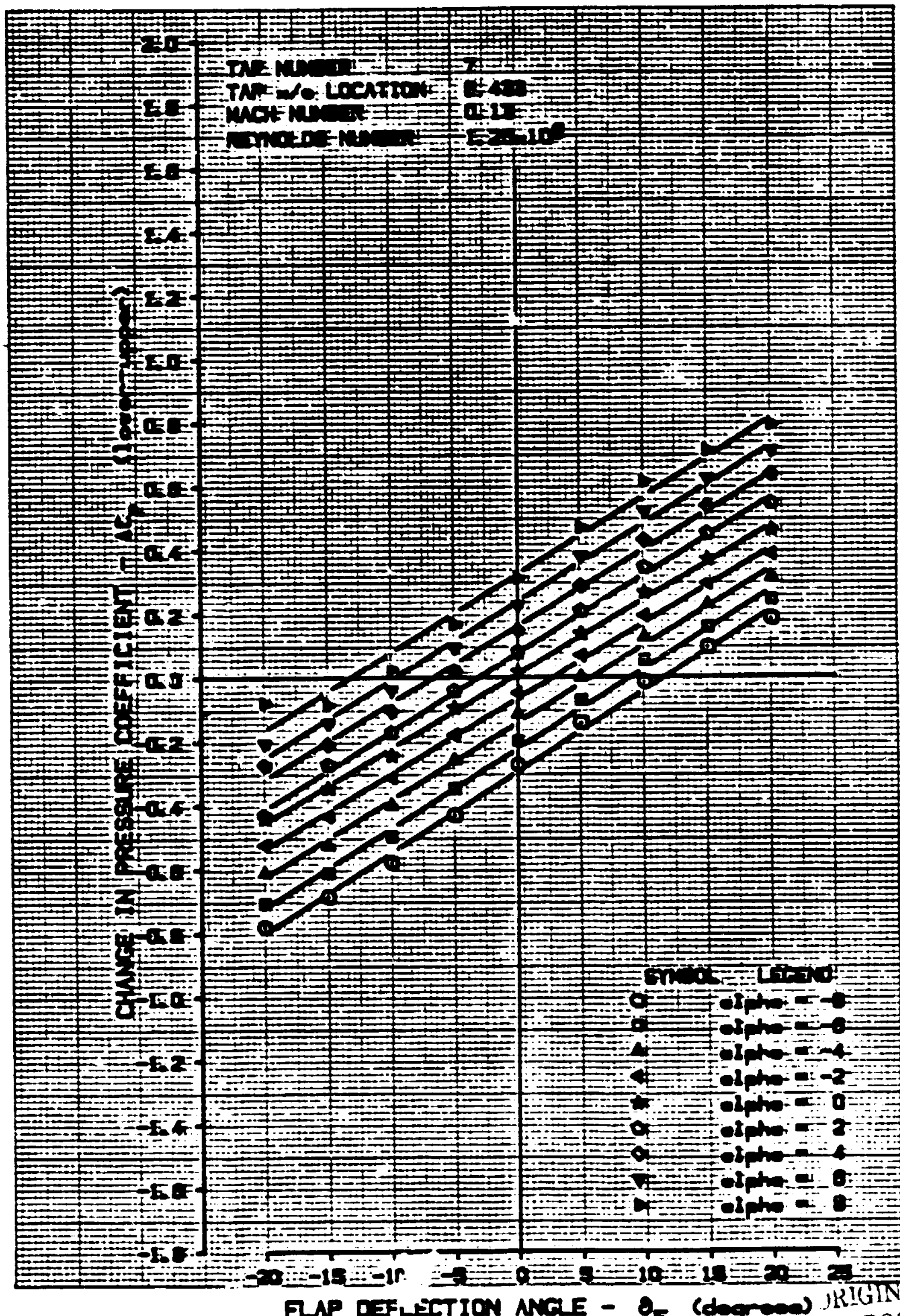
NOTE: LOWER SURFACE C_p INTERPOLATED TO UPPER SURFACE TAP LOCATION



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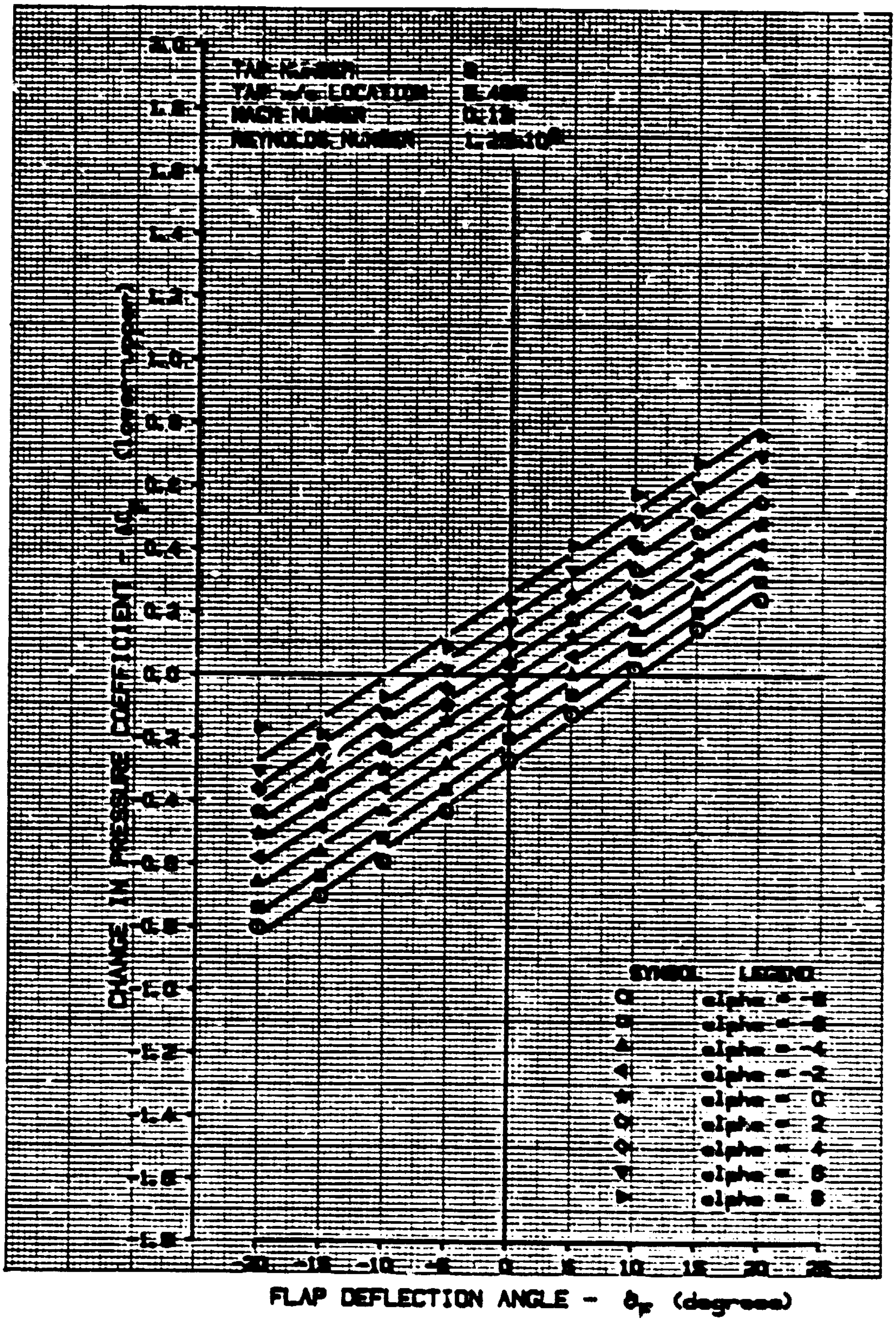
NOTE: LOWER SURFACE C_p INTERPOLATED TO UPPER SURFACE TAP LOCATION



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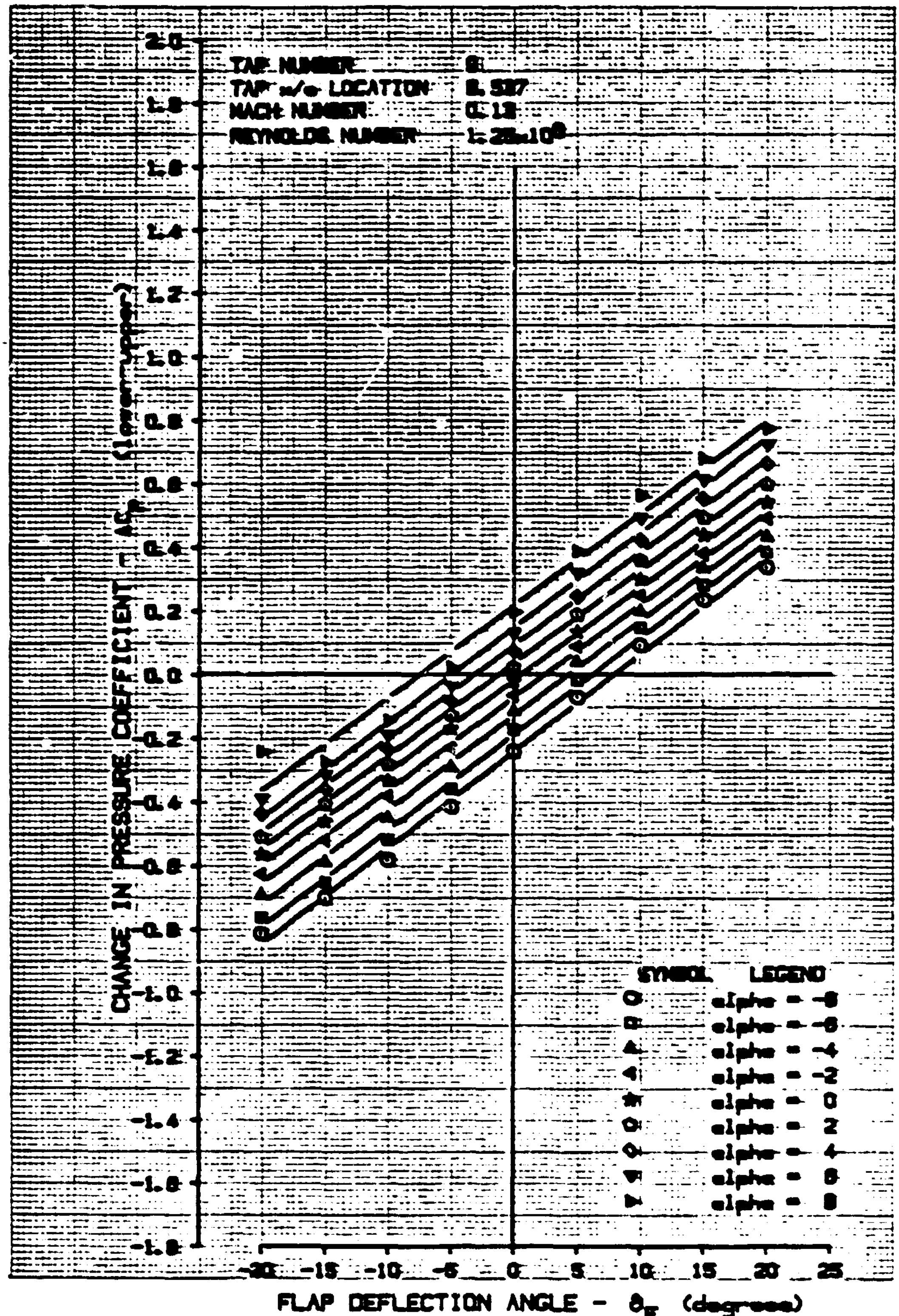
NOTE: LOWER SURFACE C_p INTERPOLATED TO UPPER SURFACE TAP LOCATION



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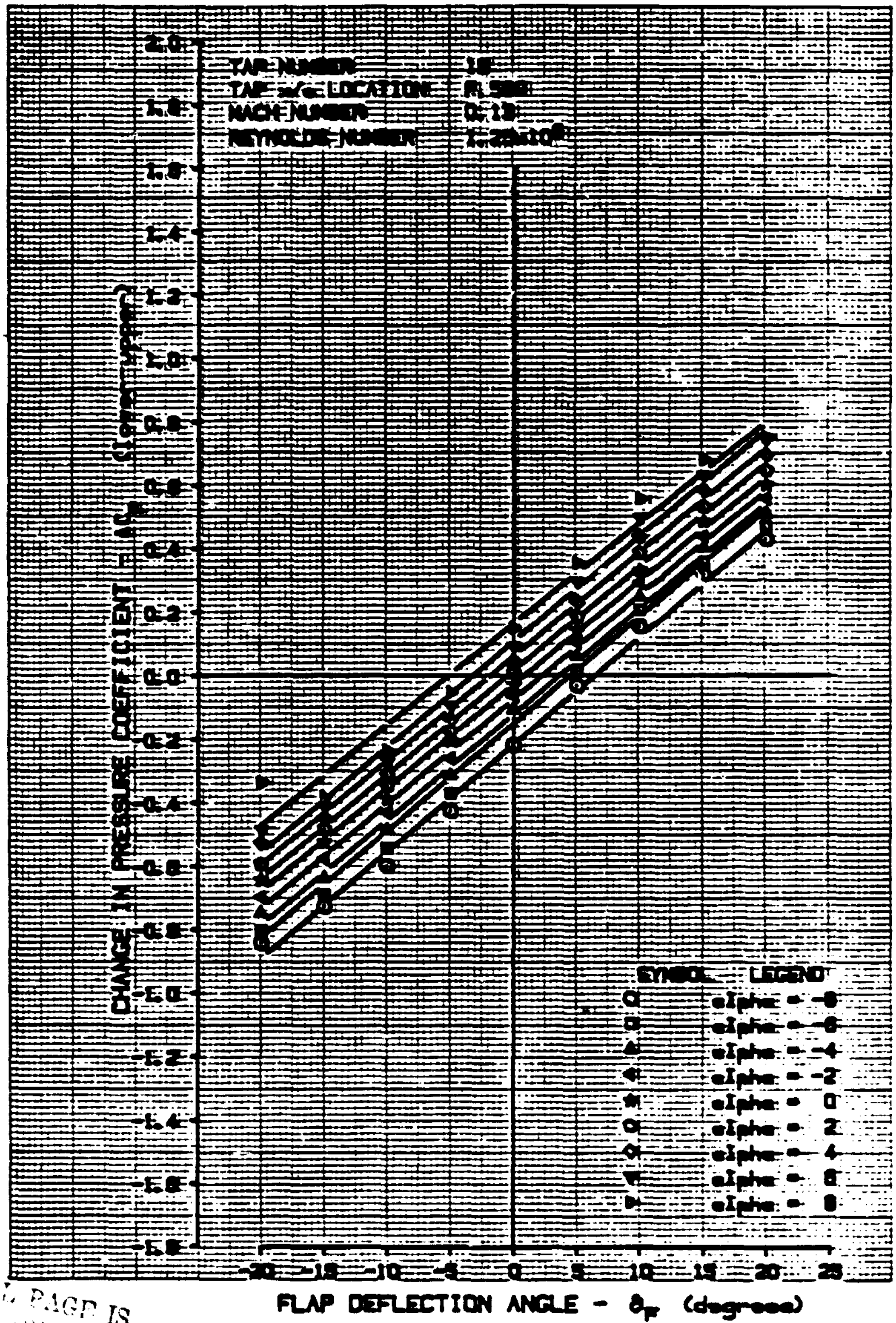
NOTE: LOWER SURFACE C_p INTERPOLATED TO UPPER SURFAC TAP LOCATION



CALC	P. FINN	5-81	REVISED	DATE	FIGURE A.1.10 EXPERIMENTAL CHANGE IN PRESSURE COEFFICIENTS - FLAP DEFLECTION SENSITIVITY	DATE 21-5-81
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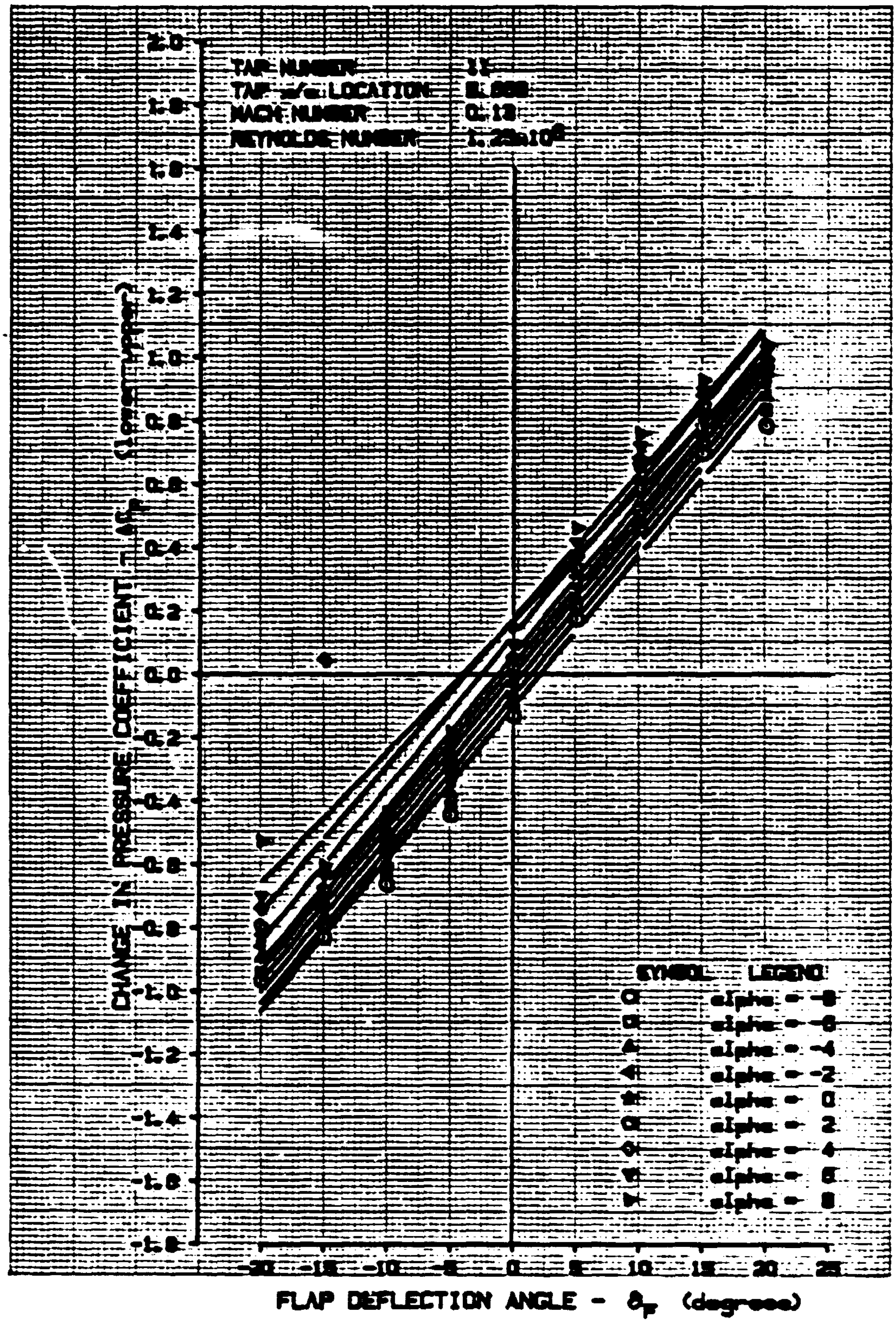
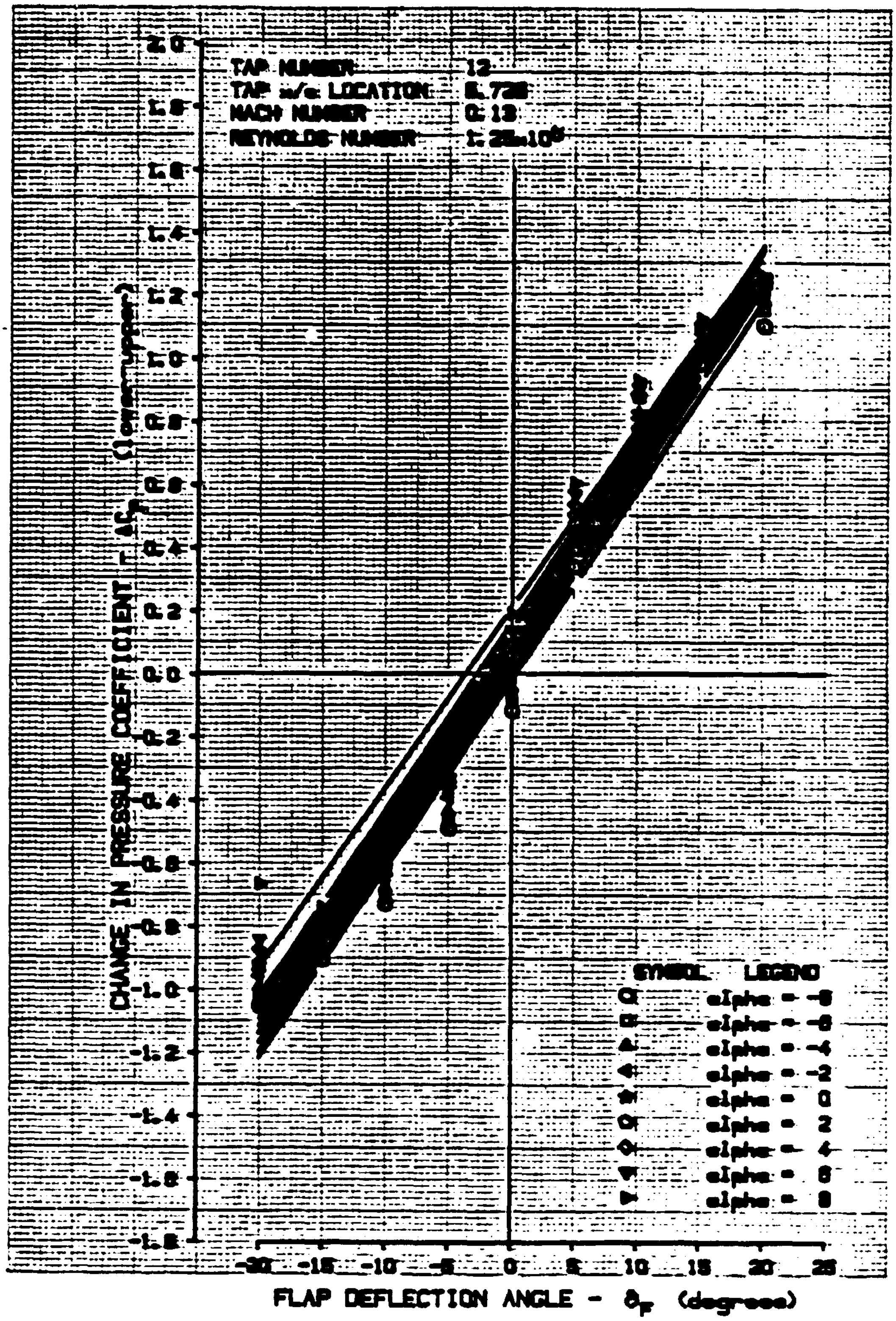
NOTE: LOWER SURFACE C_p INTERPOLATED TO UPPER SURFACE TAP LOCATION



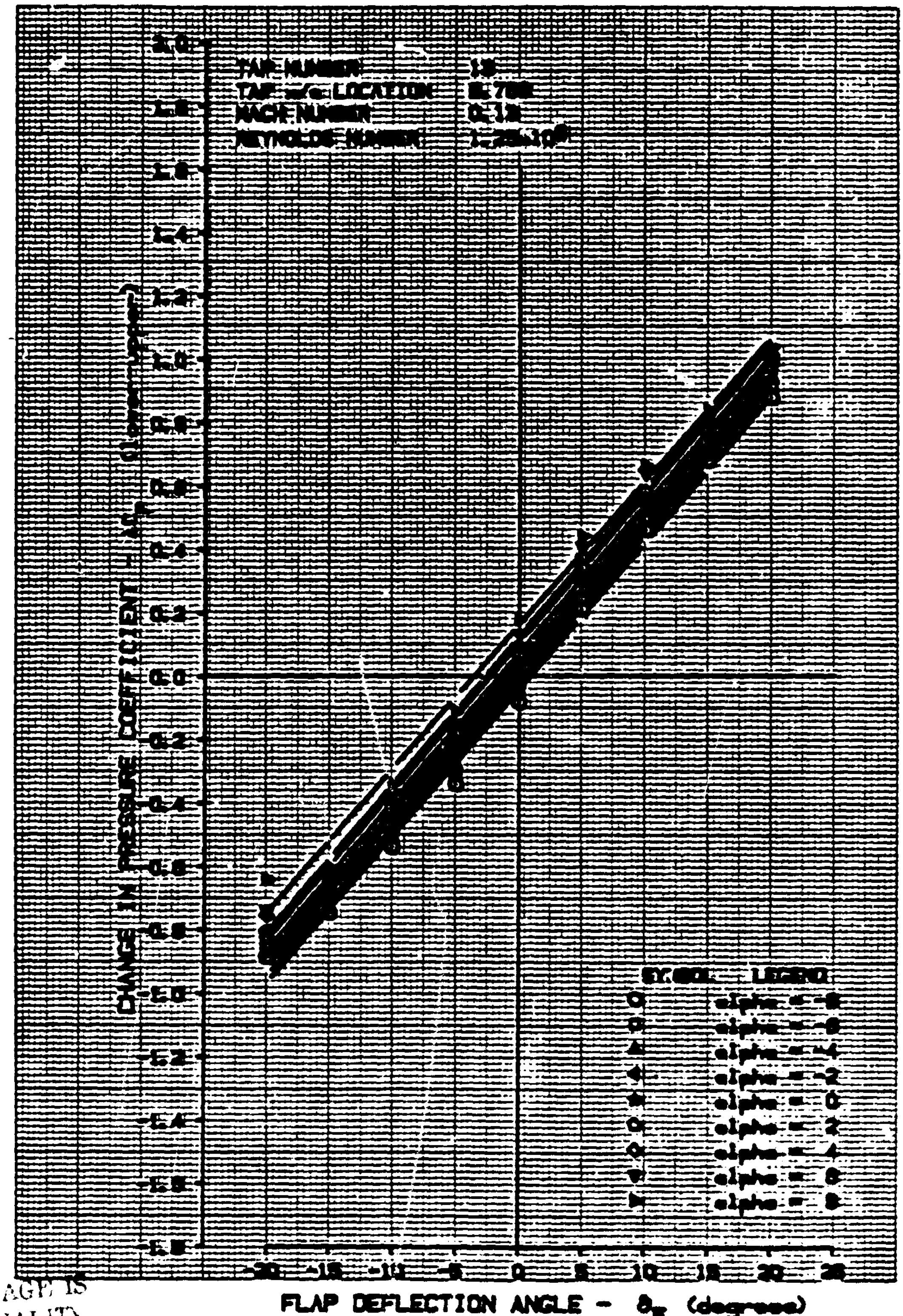
CALC	P. FINN	5-81	REVISED	DATE	FIGURE A.1.11 EXPERIMENTAL CHANGE IN PRESSURE COEFFICIENTS - FLAP DEFLECTION SENSITIVITY	DATE 21-5-81
CHECK	D. LEVY	5/25/81				
APPD						
APPD					UNIVERSITY OF KANSAS	PAGE 68

NOTE: LOWER SURFACE Cp INTERPOLATED TO UPPER SURFACE TAP LOCATION



CALC	P. FINN	5-81	REVISED	DATE	FIGURE A.1.12 EXPERIMENTAL CHANGE IN PRESSURE COEFFICIENTS - FLAP DEFLECTION SENSITIVITY	DATE 21-5-81
CHECK	D. LEVY	5/25/81				
APPD						
APPD						
					UNIVERSITY OF KANSAS	PAGE 69

NOTE: LOWER SURFACE C_p INTERPOLATED TO UPPER SURFACE TAP LOCATION



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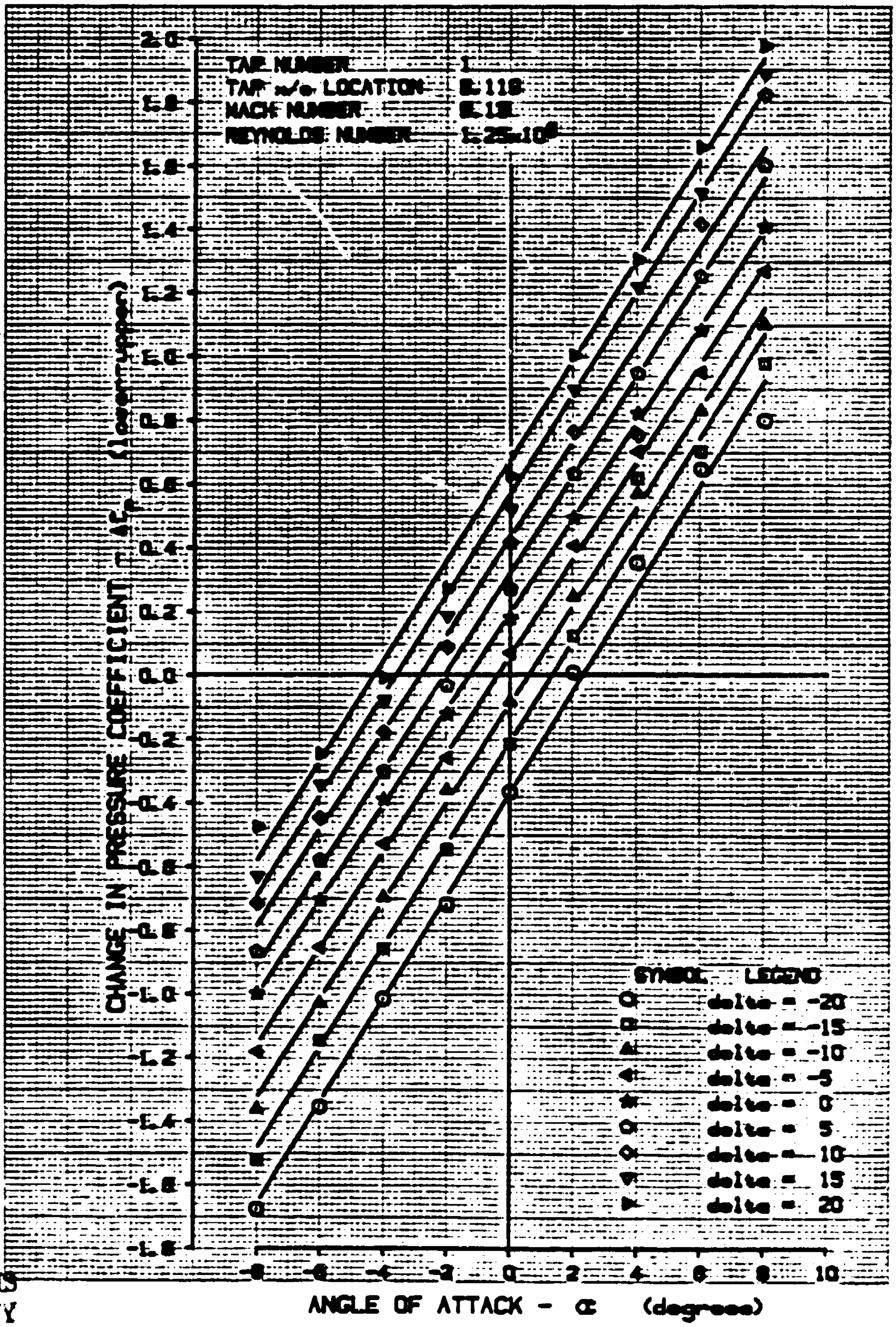
CALC	P. FINN	5-81	REVISED	DATE	FIGURE A.1.13 EXPERIMENTAL CHANGE IN PRESSURE COEFFICIENTS - FLAP DEFLECTION SENSITIVITY	DATE 21-5-81
CHECK	D. LEVY	5/25/81				
APPD						
APPD					UNIVERSITY OF KANSAS	PAGE 70

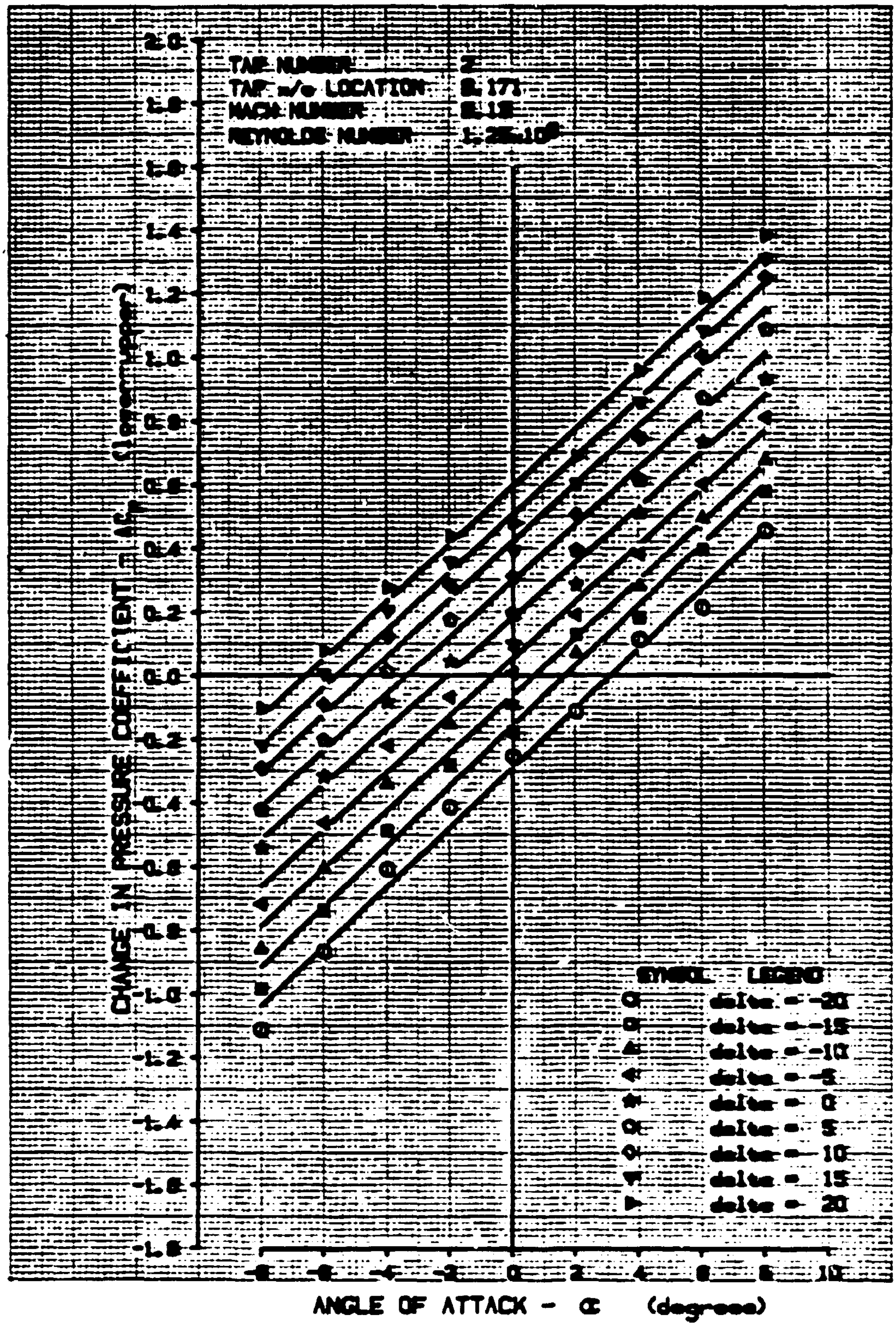
A.2 ANGLE OF ATTACK

NOTE: LOWER SURFACE C_p INTERPOLATED TO UPPER SURFACE TAP LOCATION



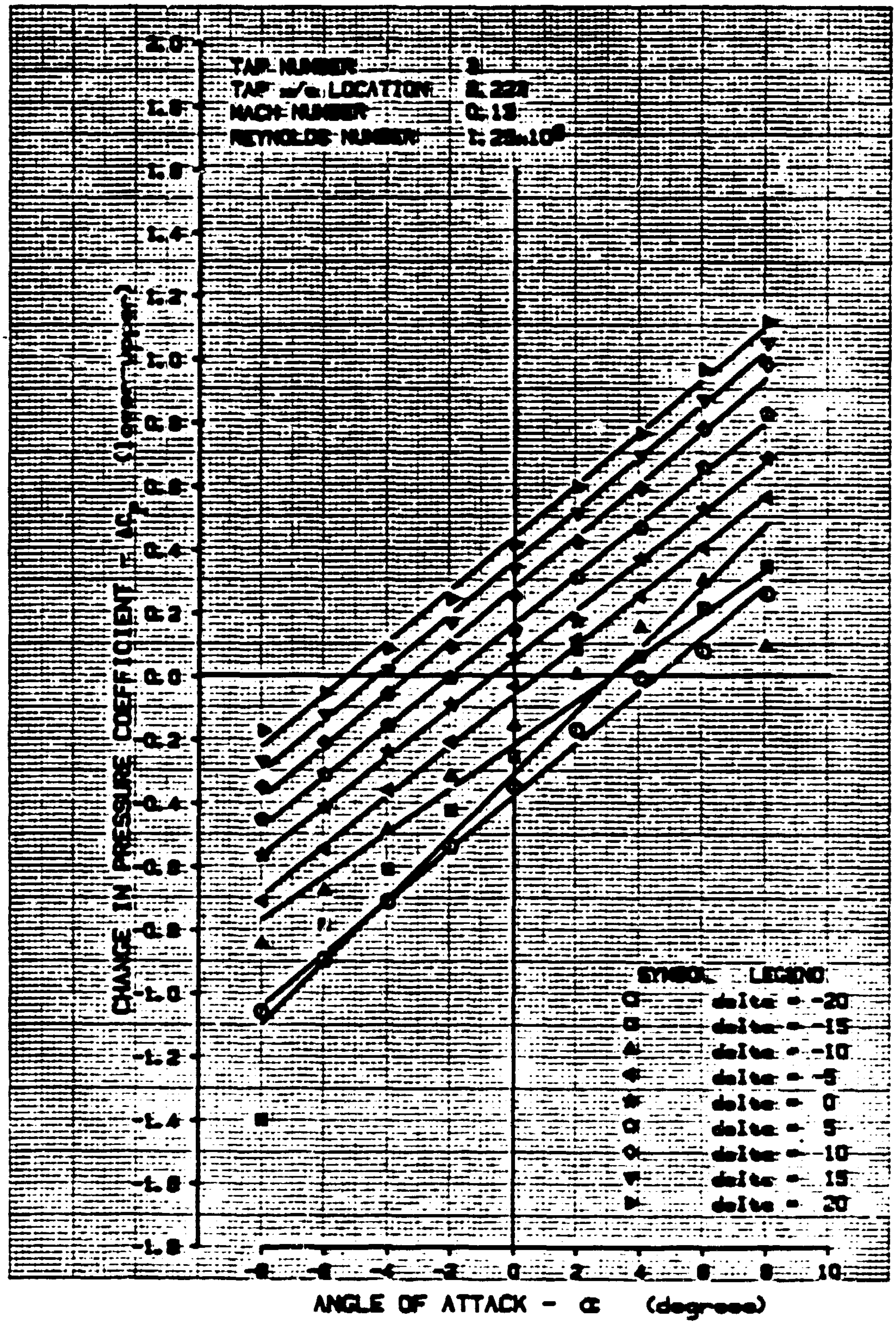
CALC	P. FINN	5-81	REVISED	DATE	FIGURE A.2.1 EXPERIMENTAL CHANGE IN PRESSURE COEFFICIENTS - ANGLE OF ATTACK SENSITIVITY	DATE 20-5-81
CHECK	D. LEVY	5/25/81				
APPD						
APPD					UNIVERSITY OF KANSAS	PAGE 72

NOTE: LOWER SURFACE Cp INTERPOLATED TO UPPER SURFACE TAP LOCATION



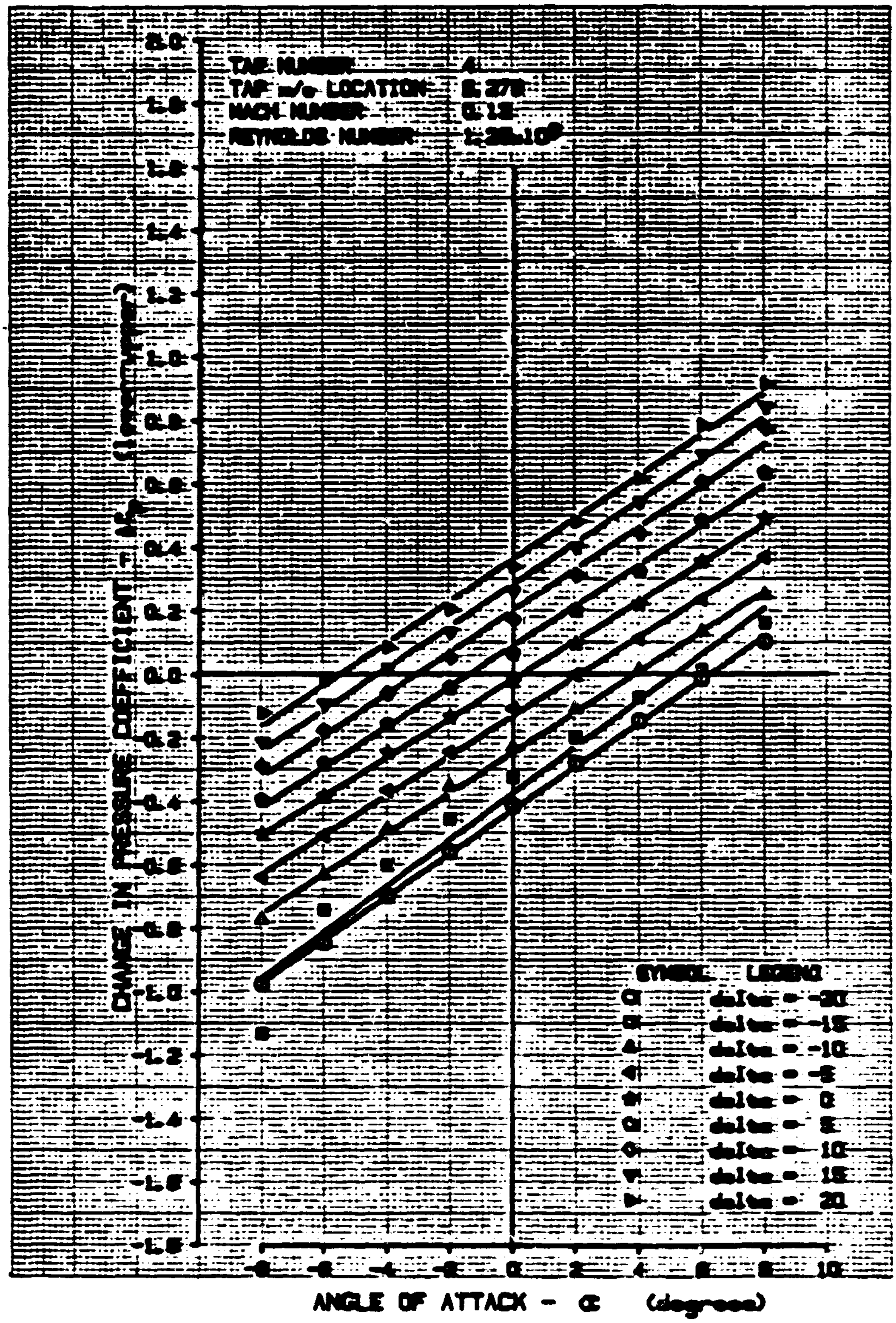
CALC	P. FINN	5-81	REVISED	DATE	FIGURE A.2.2 EXPERIMENTAL CHANGE IN PRESSURE COEFFICIENTS - ANGLE OF ATTACK SENSITIVITY	DATE 20-5-81
CHECK	D. LEVY	5/25/81				
APPD						
APPD					UNIVERSITY OF KANSAS	PAGE 73

NOTE: LOWER SURFACE Cp INTERPOLATED TO UPPER SURFACE TAP LOCATION



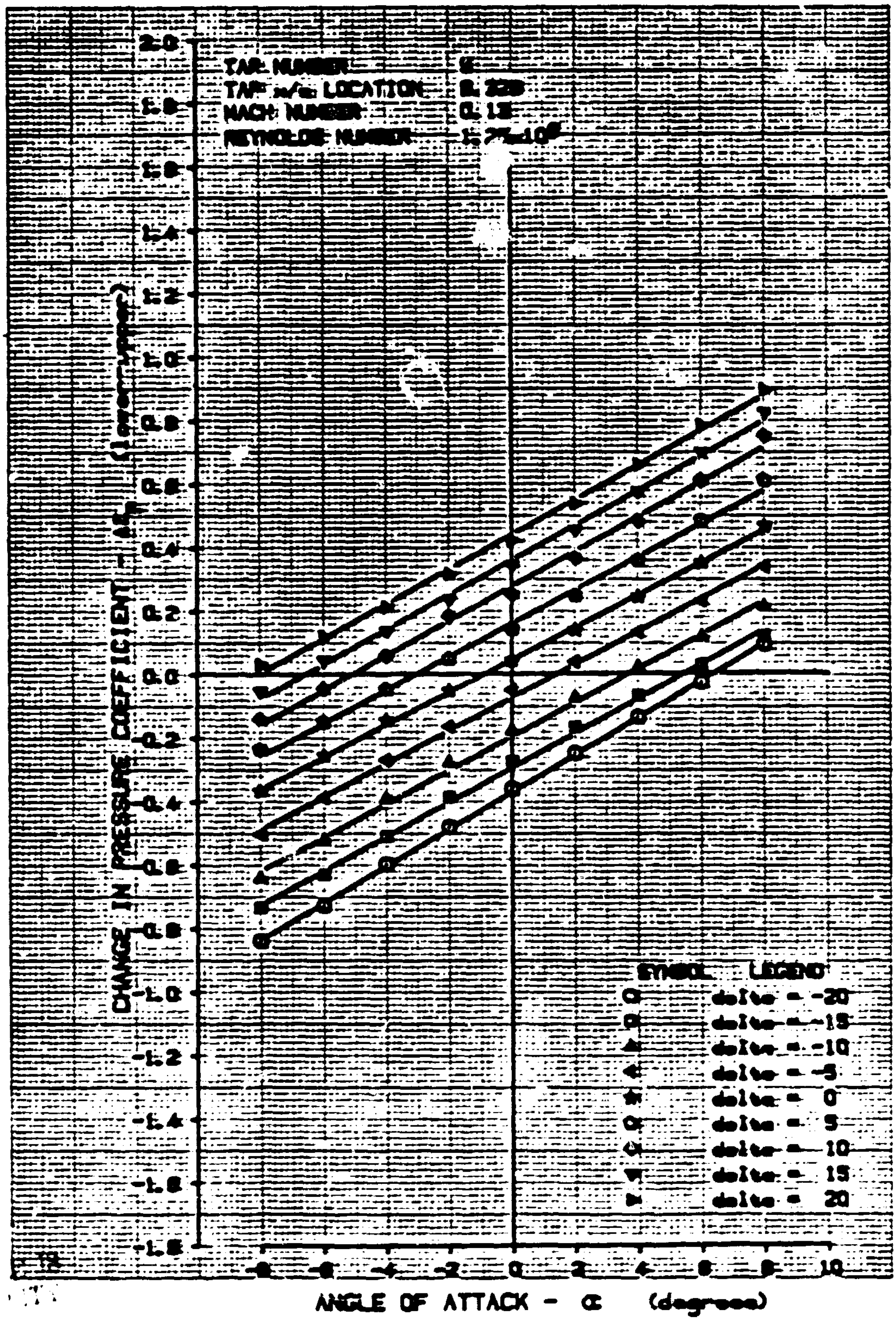
CALC	P. FINN	5-81	REVISED	DATE	FIGURE A.2.3 EXPERIMENTAL CHANGE IN PRESSURE COEFFICIENTS - ANGLE OF ATTACK SENSITIVITY	DATE 20-5-81
CHECK	D. LEVY	5/25/81				
APPD						
APPD					UNIVERSITY OF KANSAS	PAGE 74

NOTE: LOWER SURFACE C_p INTERPOLATED TO UPPER SURFACE TAP LOCATION



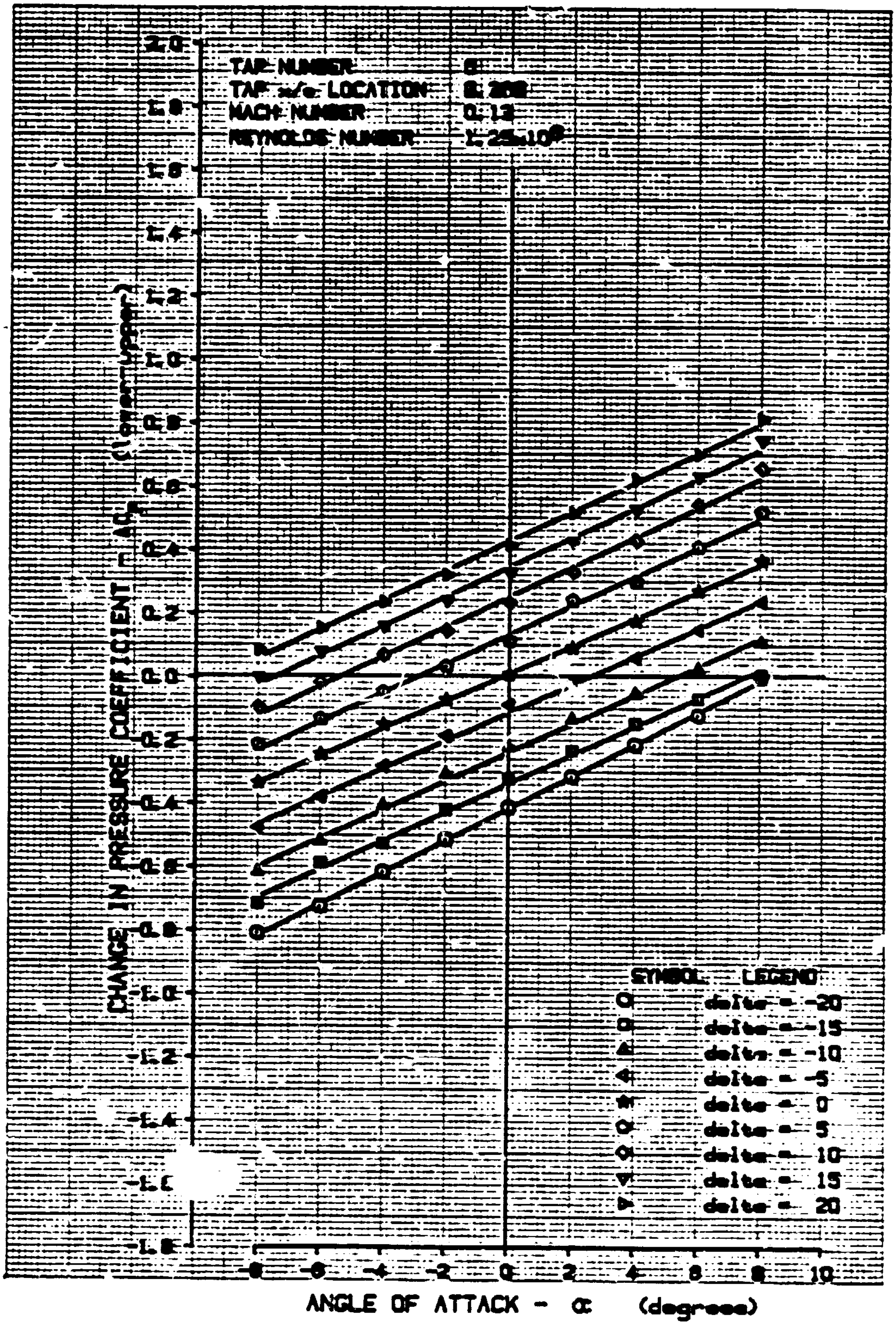
CALC	P. FINN	5-81	REVISED	DATE	FIGURE A.2.4 EXPERIMENTAL CHANGE IN PRESSURE COEFFICIENTS - ANGLE OF ATTACK SENSITIVITY	DATE 20-5-81
CHECK	D. LEVY	5/20/81				
APPD						
APPD					UNIVERSITY OF KANSAS	PAGE 75

NOTE: LOWER SURFACE Cp INTERPOLATED TO UPPER SURFACE TAP LOCATION



CALC	P. FINN	5-81	REVISED	DATE	FIGURE A.2.5 EXPERIMENTAL CHANGE IN PRESSURE COEFFICIENTS - ANGLE OF ATTACK SENSITIVITY	DATE 20-5-81
CHECK	D. LEVY	5/25/81				
APPD						
APPD					UNIVERSITY OF KANSAS	PAGE 76

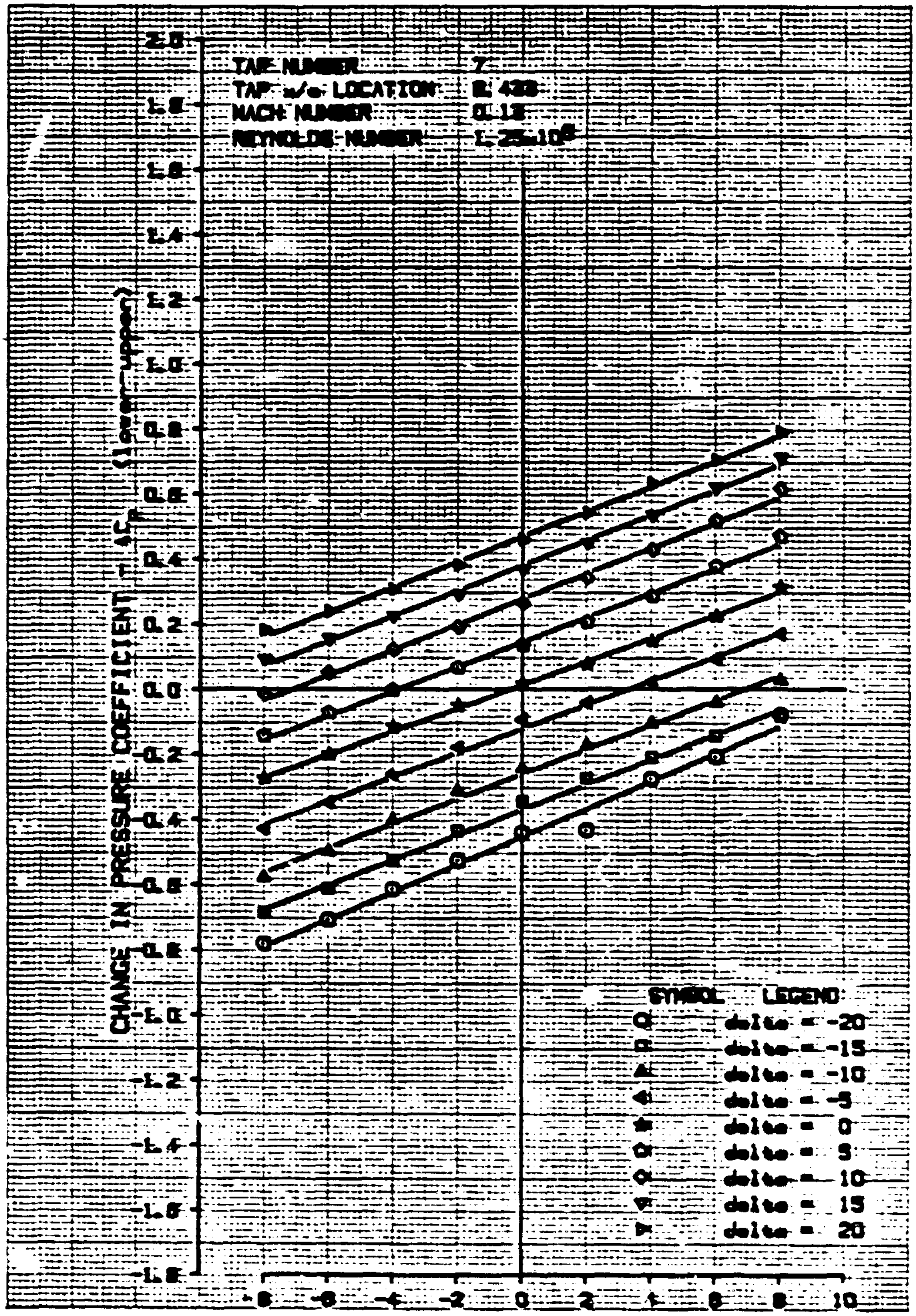
NOTE: LOWER SURFACE C_p INTERPOLATED TO UPPER SURFACE TAP LOCATION



CALC	F. FINN	5-81	REVISED	DATE	FIGURE A.2.8 EXPERIMENTAL CHANGE IN PRESSURE COEFFICIENTS - ANGLE OF ATTACK SENSITIVITY
CHECK	D. LEVY	5/25/81			
APPD					
APPD					UNIVERSITY OF KANSAS

DATE 20-5-81

NOTE: LOWER SURFACE Cp INTERPOLATED TO UPPER SURFACE TAP LOCATION



CALC	P. FINN	5-81	REVISED	DATE	FIGURE A.2.7 EXPERIMENTAL CHANGE IN PRESSURE COEFFICIENTS - ANGLE OF ATTACK SENSITIVITY	DATE 20-5-81
CHECK	D. LEVY	5/25/81				
APPD						
APPD						
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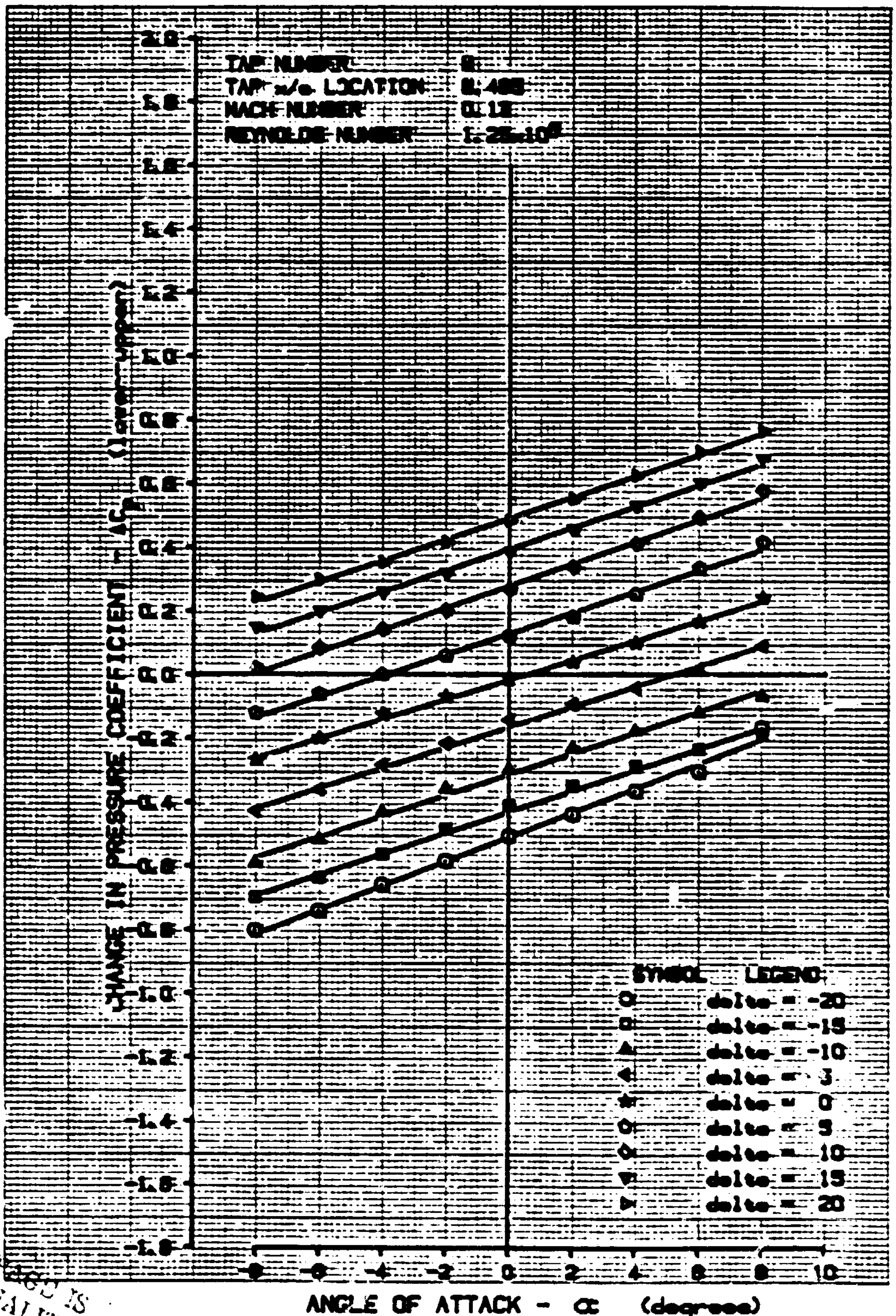
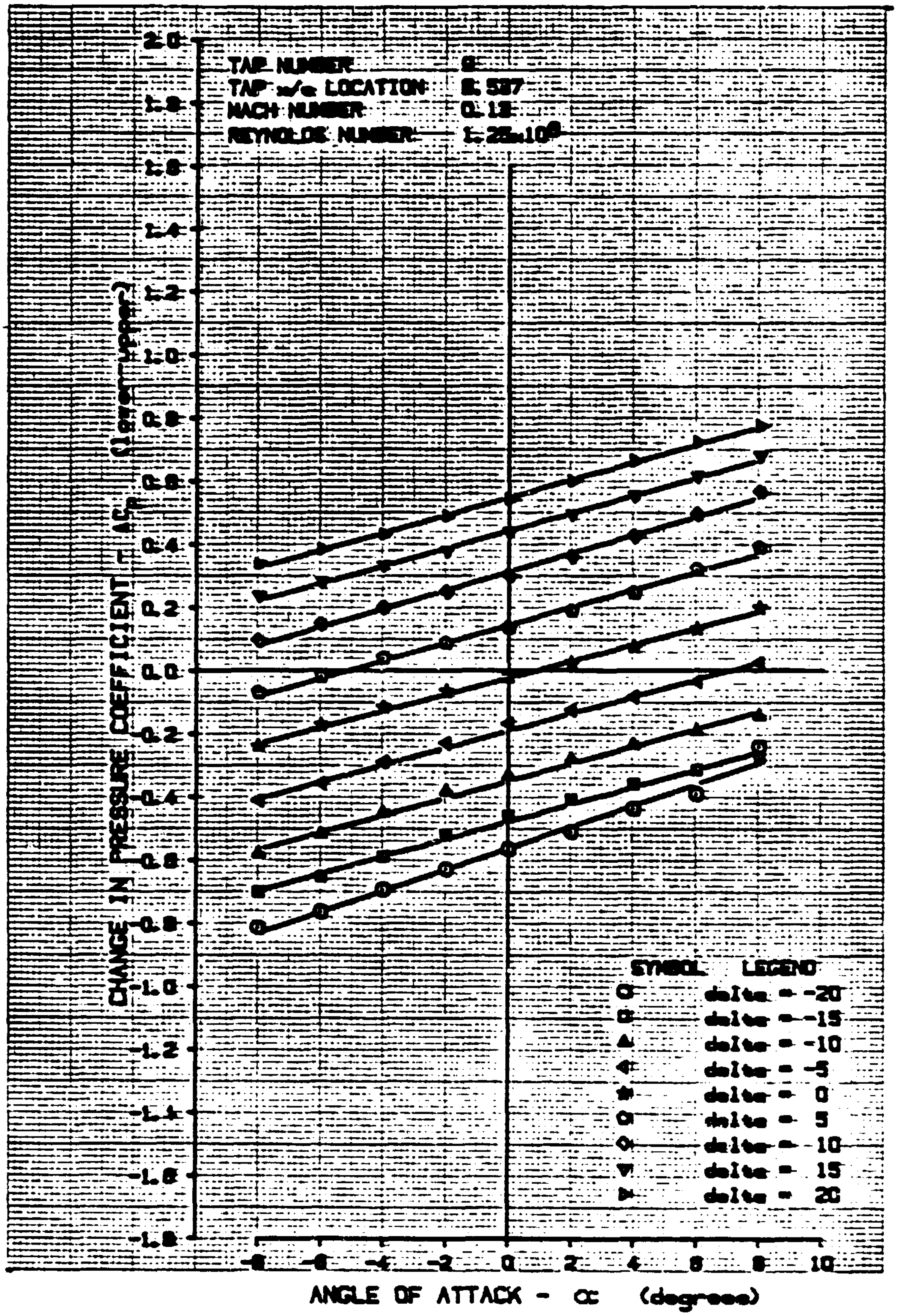
NOTE: LOWER SURFACE C_p INTERPOLATED TO UPPER SURFACE TAP LOCATION



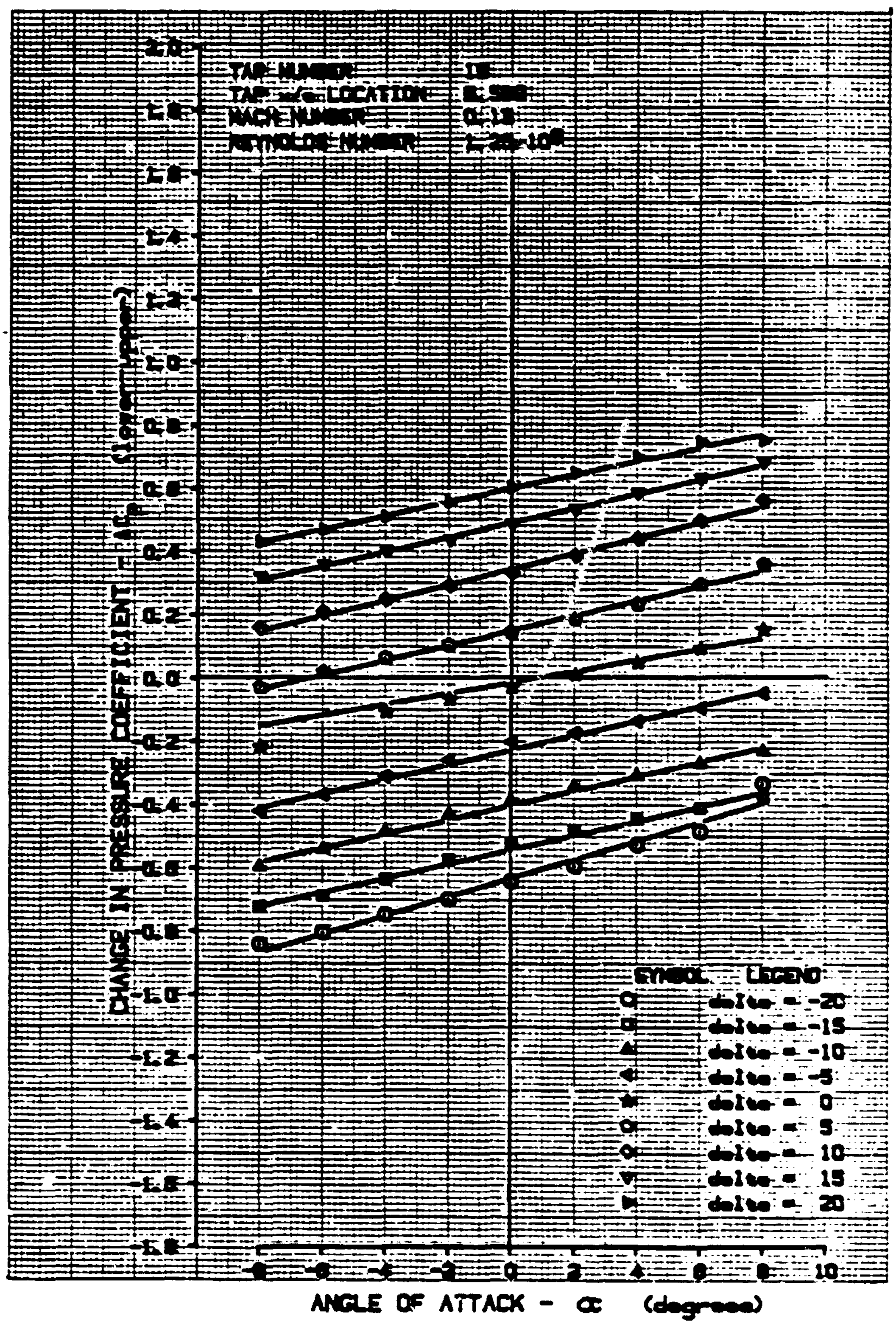
CALC	P. FINN	5-81	REVISED	DATE	FIGURE A.2.8 EXPERIMENTAL CHANGE IN PRESSURE COEFFICIENTS - ANGLE OF ATTACK SENSITIVITY	DATE 20-5-81
CHECK	D. LEVY	5/25/81				
APPD						
APPD					UNIVERSITY OF KANSAS	PAGE 79

NOTE: LOWER SURFACE Cp INTERPOLATED TO UPPER SURFACE TAP LOCATION



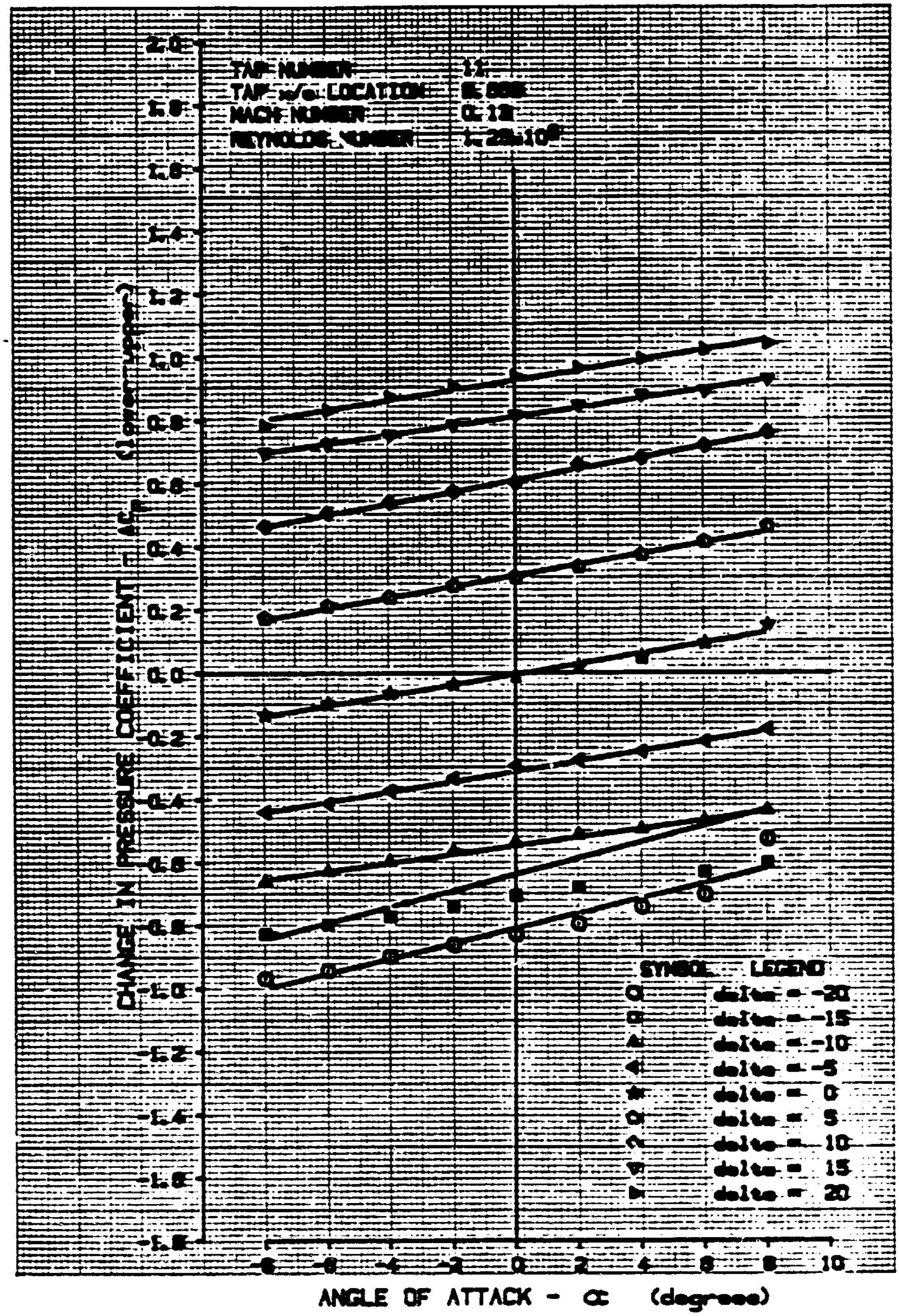
CALC	P. FINN	5-81	REVISED	DATE	FIGURE A.2.9 EXPERIMENTAL CHANGE IN PRESSURE COEFFICIENTS - ANGLE OF ATTACK SENSITIVITY	DATE 21-5-81
CHECK	D. LEVY	5/25/81				
APPD						
APPD					UNIVERSITY OF KANSAS	PAGE 80

NOTE: LOWER SURFACE C_p INTERPOLATED TO UPPER SURFACE TAP LOCATION



CALC	P. FINN	5-81	REVISED	DATE	FIGURE A. 2. 10 EXPERIMENTAL CHANGE IN PRESSURE COEFFICIENTS - ANGLE OF ATTACK SENSITIVITY	DATE 21-5-81
CHECK	D. LEVY	5/25/81				
APPD						
APPD					UNIVERSITY OF KANSAS	PAGE 81

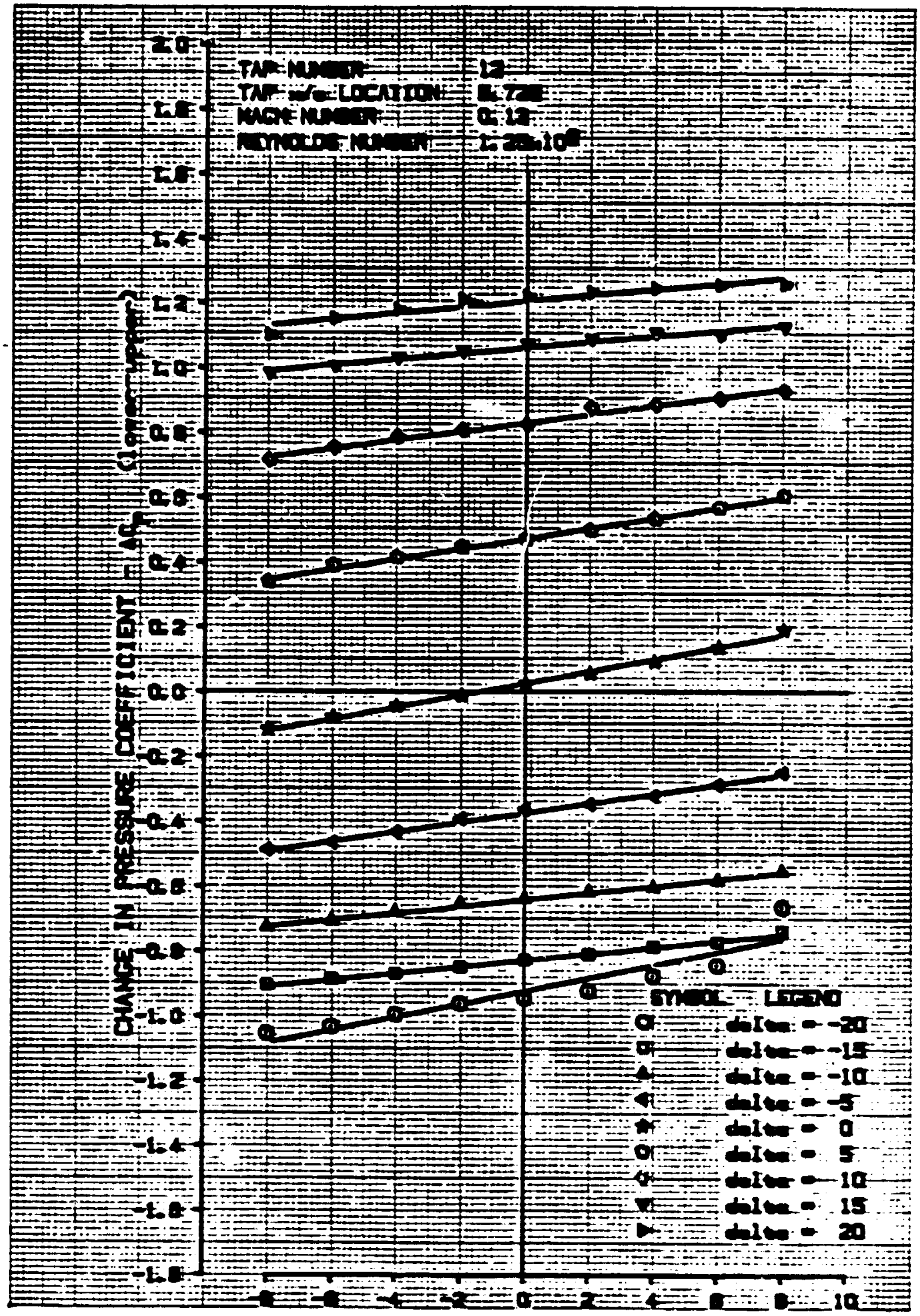
NOTE: LOWER SURFACE C_p INTERPOLATED TO UPPER SURFACE TAP LOCATION



CALC	P. FINN	5-81	REVISED	DATE	FIGURE A.2.11	EXPERIMENTAL CHANGE IN PRESSURE COEFFICIENTS - ANGLE OF ATTACK SENSITIVITY
CHECK	D. LEVY	5/25/81				
APPD						
APPD					UNIVERSITY OF KANSAS	

DATE 21-5-81

NOTE: LOWER SURFACE Cp INTERPOLATED TO UPPER SURFACE TAP LOCATION



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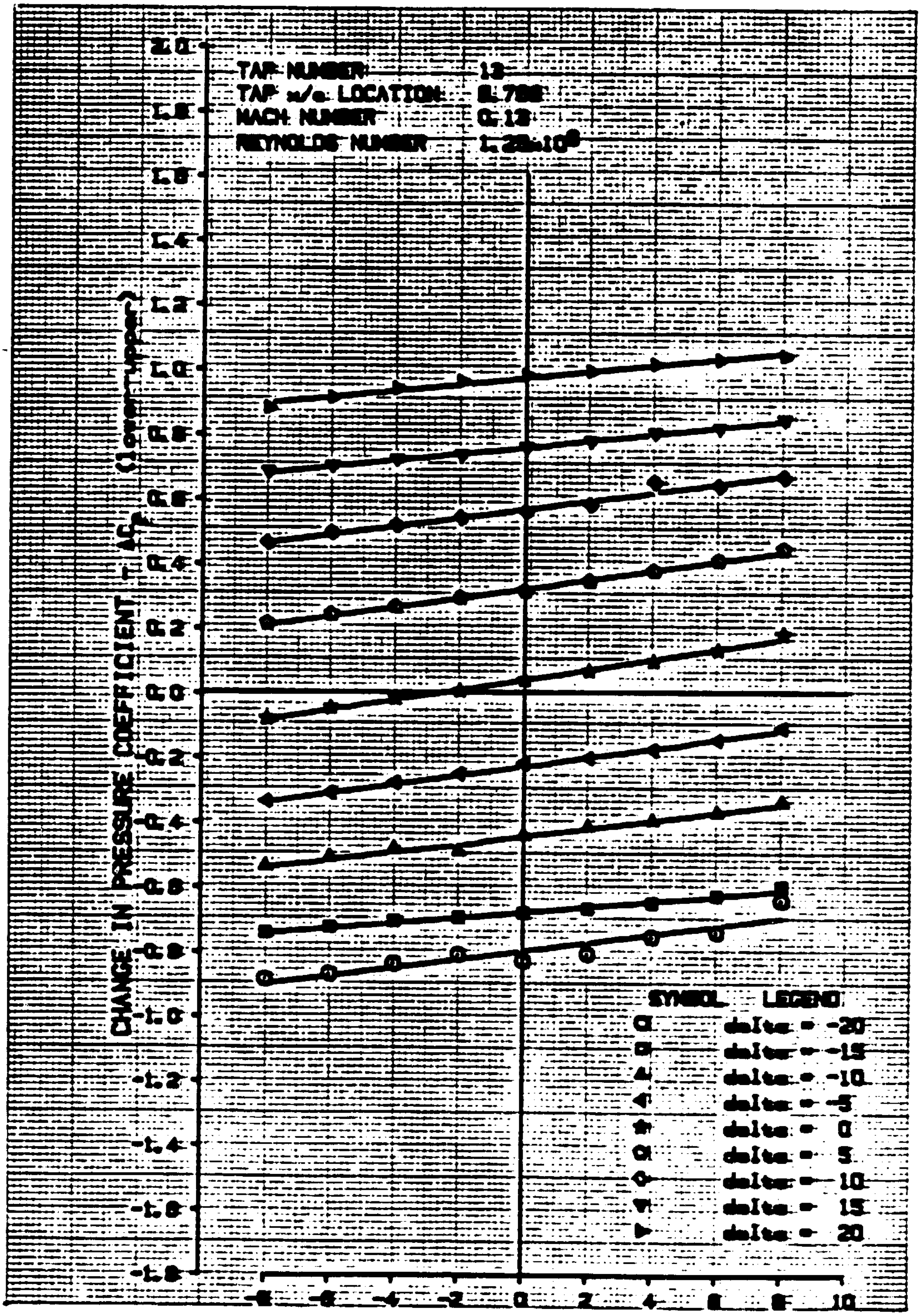
CALC	P. FINN	5-81	REVISED	DATE	FIGURE A.2.12 EXPERIMENTAL CHANGE IN PRESSURE COEFFICIENTS - ANGLE OF ATTACK SENSITIVITY	DATE 21-5-81
CHECK	D. LEVY	5/25/81				
APPD						
APPD					UNIVERSITY OF KANSAS	PAGE 83

NOTE: LOWER SURFACE C_p INTERPOLATED TO UPPER SURFACE TAP LOCATION



CALC	P. FINN	5-81	REVISED	DATE	FIGURE A.2.13 EXPERIMENTAL CHANGE IN PRESSURE COEFFICIENTS - ANGLE OF ATTACK SENSITIVITY	DATE 21-5-81
CHECK	D. LEVY	5/25/81				
APPD						
APPD					UNIVERSITY OF KANSAS	PAGE 84

APPENDIX B. PRESSURE TRANSDUCER CALIBRATION PROGRAM

```
240: wrt 4
241: wrt 4,"          DELTA P  PRESSURE TRANSDUCER CALIBRATION"
242: wrt 4
243: wrt 4,"  THE PRESSURE TRANSDUCER WILL BE CALIBRATED AGAINST THE TUNNEL"
244: wrt 4," MANOMETER BOARD LOCATED ON THE NORTH SIDE OF THE TUNNEL BELL"
245: wrt 4,"   THE TRANSDUCER MUST BE HOOKED TO CHANNEL 12 OF THE DAS"
246: wrt 4
247: wrt 4
248: wrt 4,"PROCEEDURE:"
249: wrt 4
250: wrt 4," TO CALIBRATE, THE TUNNEL WILL BE RUN AT VARIOUS ASSIGNED SPEEDS."
251: wrt 4," THE hp 9825 WILL RECORD THE PRESSURE TRANSDUCER OUTPUT AND "
252: wrt 4," THE OPERATOR WILL ADJUST THE TUNNEL SPEED TO THE MANOMETER VALUE"
253: wrt 4," REQUESTED BY THE CALCULATOR DISPLAY"
254: wrt 4;wrt 4
255: ent "DATE   TRANSDUCER NUMBER",D$
256: wtb 5,12+6
257: wrt 6;wrt 6;wrt 6;wrt 6,"          PRESSURE TRANSDUCER CALIBRATION  ",D$
258: wrt 6,"    ",G$
259: wrt 6,"   MANOMETER Q             TRANSDUCER OUTPUT"
260: csiz 2,2,1,0
261: ent "DO YOU WISH A GRAPH ?  Y or N",A$
262: if cap(A$)="Y";csiz 2,2,1,0
263: if cap(A$)="Y";fxd 0;scl 0,35,0,2;xax 0,.5,0,2,2;yax 0,5,0,35,1
264: if cap(A$)="Y";plt 8,-.5,-1;csiz 2,2,1,0
265: if cap(A$)="Y";lbl " TUNNEL DYNAMIC PRESSURE - Q (cm Al)"
266: if cap(A$)="Y";plt -5,.6,-1;csiz 2,2,1,90
267: if cap(A$)="Y";lbl " TRANSDUCER OUTPUT - Q1 (mV)"
268: if cap(A$)="Y";csiz 2.5,2,1,0;plt 5,-.8,-1
269: if cap(A$)="Y";lbl " PRESSURE TRANSDUCER CALIBRATION  ",D$
270: if cap(A$)="Y";plt 2.5,2.4,-1;csiz 2,2,1,0
271: lbl "Q = (TUNNEL MANOMETER * SIN30)"
272: for Q=0 to 35 by 5
273: fxd 0;0→S
274: dsp "TUNNEL Q (cmAl)",Q,"CONT W/RDY";stp
275: for I=1 to 50
276: red 3,A,B
277: if B>1;-A→A
278: A+S→S
279: next I
280: fmt 4,2x,f4.0,20x,f10.3
281: wrt 6.4,Q,20S
282: if cap(A$)="Y";plt Q,-20S;pen;cplt -.165,-.05;lbl "*"
283: next Q
```

APPENDIX C

THEORETICAL PRESSURE PROFILE DATA

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C.1 SAMPLE LISTING OF SEAP OUTPUT

LOAD SUMMARY SHEET--ITERATION NUMBER 4

DSDELTA P THEORETICAL PRESSURE DISTRIBUTION

MACH NUMBER = 0.13000 REFERENCE CHORD (BASIS FOR ALL COEFFICIENT NORMALIZATION) = 1.38300 FT.

REYNOLDS NO. = 1.25030 MILLION ANGLE OF ATTACK (VALUE OF (ALPHA = 0)) = 3.00000 DEG.

LONGEST CHORDLINE = 1.38353 FEET (ALPHA0--ANGLE DEFINED W.R.T. REFERENCE LINE) (ALPHAT--ANGLE DEFINED W.R.T. LONGEST CHORDLINE)

ANGLE BETWEEN LONGEST CHORDLINE AND REFERENCE LINE = 1.48935 DEG. (POSITIVE FOR REFERENCE LINE BELOW THE LONGEST CHORDLINE)

NORMAL FORCE COEFFICIENTS
(CN)PRESS. = 0.15716
(CN)SHEAR = -0.00031
CN = 0.15713

AXIAL FORCE COEFFICIENTS
(CA)PRESS. = -0.00455
(CA)SHEAR = 0.01498
CA = 0.01014

MOMENT COEFFICIENTS
(ABOUT NOSE) (CM)PRESS. = -0.00833
(CM)SHEAR = 0.00070
CM = -0.00763

LIFT COEFFICIENTS
(CL)PRESS. = 0.15716
(CL)SHEAR = -0.00078
CL = 0.15638

DRAG COEFFICIENTS
(CD)PRESS. = 0.00368
(CD)SHEAR = 0.01498
CD = 0.01834

MOMENT COEFFICIENTS
(CM)ABOUT NOSE = -0.00763
(CM)QUARTER CHORD = 0.03165

DRAG COEFFICIENT COMPUTED BY SQUIRE-YOUNG FORMULA = 0.01595

ZEROTH ITERATION PRESSURE DRAG = -0.01341

TRANSITION POINTS: X/C(LOWER) = 0.14532 X/C(UPPER) = 0.09327

LONGEST CHORDLINE SYSTEM X/C	Z/C	BASIC REFERENCE SYSTEM X/C	Z/C	S/C	CP	CF	DSTAR/C	V/V0
1.00026	[illegible]	0.99986	[illegible]	[illegible]	[illegible]	0.00501	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
0.09352	[illegible]	0.09114	-0.09258	0.91272	-0.98370	0.00011	0.00027	1.40900
0.08312	-0.08709	0.08081	-0.08982	0.92342	-0.71187	0.01310	0.00026	1.30798
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1.00026	0.00300	1.00000	-0.02300	2.11268	0.75003	0.00468	0.00000	[illegible]

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C.2 PRESSURE DISTRIBUTION DATA AS INPUT TO HP9825 A

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

ANGLE OF ATTACK = 0 FLAP DEFLECTION ANGLE = 0
FILE NUMBER 34

RESULTS OF SEAP DATA

TAP NUMBER	x/c location	Cp upper	Cp lower
1	0.060	-1.198	-1.198
2	0.076	-1.135	-1.135
3	0.084	-1.396	-1.396
4	0.094	-1.354	-1.354
5	0.108	-1.216	-1.216
6	0.121	-1.277	-1.277
7	0.133	-1.450	-1.450
8	0.143	-1.365	-1.365
9	0.155	-1.081	-1.081
10	0.169	-0.881	-0.881
11	0.184	-0.743	-0.743
12	0.205	-0.648	-0.648
13	0.228	-0.572	-0.572
14	0.250	-0.334	-0.334
15	0.381	-0.264	-0.264
16	0.416	-0.136	-0.136
17	0.480	-0.115	-0.115
18	0.680	-0.103	-0.103
19	0.715	-0.076	-0.076
20	0.750	-0.070	-0.070
21	0.785	-0.042	-0.042
22	0.820	-0.029	-0.029
23	1.000	0.634	0.634

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

ANGLE OF ATTACK = 3 FLAP DEFLECTION ANGLE = 0
FILE NUMBER 35

RESULTS OF SEAP DATA

TAP NUMBER	x/c location	Cp upper	Cp lower
1	0.060	-1.860	-0.612
2	0.076	-1.728	-0.603
3	0.084	-1.989	-0.849
4	0.094	-1.877	-0.854
5	0.108	-1.665	-0.777
6	0.121	-1.702	-0.855
7	0.133	-1.887	-1.019
8	0.143	-1.786	-0.965
9	0.155	-1.445	-0.744
10	0.169	-1.192	-0.591
11	0.184	-1.009	-0.490
12	0.205	-0.881	-0.423
13	0.228	-0.788	-0.364
14	0.250	-0.476	-0.193
15	0.381	-0.381	-0.145
16	0.416	-0.209	-0.057
17	0.480	-0.177	-0.050
18	0.680	-0.159	-0.045
19	0.715	-0.119	-0.035
20	0.750	-0.115	-0.028
21	0.785	-0.080	-0.006
22	0.820	-0.063	-0.002
23	1.000	0.630	0.630

C - 2

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

ANGLE OF ATTACK = 6 FLAP DEFLECTION ANGLE = 0
FILE NUMBER 36

RESULTS OF SEAP DATA

TAP NUMBER	x/c location	Cp upper	Cp lower
1	0.060	-2.624	-0.093
2	0.076	-2.407	-0.124
3	0.084	-2.670	-0.345
4	0.094	-2.489	-0.382
5	0.108	-2.190	-0.355
6	0.121	-2.194	-0.444
7	0.133	-2.383	-0.598
8	0.143	-2.240	-0.578
9	0.155	-1.822	-0.418
10	0.169	-1.512	-0.308
11	0.184	-1.283	-0.240
12	0.205	-1.121	-0.198
13	0.228	-1.008	-0.156
14	0.250	-0.626	-0.047
15	0.381	-0.510	-0.018
16	0.416	-0.298	0.033
17	0.480	-0.248	0.026
18	0.680	-0.221	0.022
19	0.715	-0.163	0.016
20	0.750	-0.162	0.024
21	0.785	-0.119	0.039
22	0.820	-0.096	0.036
23	1.000	0.624	0.624

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

ANGLE OF ATTACK = 0 FLAP DEFLECTION ANGLE = 5
FILE NUMBER 37

RESULTS OF SEAP DATA

TAP NUMBER	x/c location	Cp upper	Cp lower
1	0.062	-1.340	-1.022
2	0.073	-1.285	-0.949
3	0.083	-1.572	-1.148
4	0.094	-1.501	-1.202
5	0.107	-1.359	-1.063
6	0.123	-1.486	-1.116
7	0.135	-1.627	-1.266
8	0.148	-1.324	-1.146
9	0.163	-1.032	-0.886
10	0.181	-0.903	-0.714
11	0.203	-0.596	-0.436
12	0.296	-0.418	-0.275
13	0.404	-0.214	-0.076
14	0.652	-0.158	-0.008
15	0.671	-0.027	0.215
16	0.688	-0.060	0.157
17	0.704	-0.039	0.144
18	0.720	0.020	0.124
19	0.741	-0.022	0.068
20	0.795	-0.067	0.033
21	0.824	-0.043	0.008
22	0.852	-0.102	-0.088
23	1.000	0.760	0.760

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

ANGLE OF ATTACK = 3 FLAP DEFLECTION ANGLE = 5
FILE NUMBER 38

RESULTS OF SEAP DATA

TAP NUMBER	x/c location	Cp upper	Cp lower
1	0.062	-1.607	-0.748
2	0.073	-1.513	-0.712
3	0.083	-1.803	-0.912
4	0.094	-1.703	-0.984
5	0.107	-1.524	-0.881
6	0.123	-1.632	-0.951
7	0.135	-1.767	-1.107
8	0.148	-1.452	-1.006
9	0.163	-1.141	-0.773
10	0.181	-1.001	-0.619
11	0.203	-0.644	-0.384
12	0.296	-0.438	-0.250
13	0.404	-0.178	-0.105
14	0.652	-0.097	-0.060
15	0.671	0.122	0.078
16	0.688	0.091	0.009
17	0.704	0.123	-0.020
18	0.720	0.158	-0.022
19	0.741	0.080	-0.039
20	0.795	0.017	-0.053
21	0.824	0.039	-0.077
22	0.852	-0.024	-0.174
23	1.000	0.750	0.750

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

ANGLE OF ATTACK = 6 FLAP DEFLECTION ANGLE = 5
FILE NUMBER 39

RESULTS OF SEAP DATA

TAP NUMBER	x/c location	Cp upper	Cp lower
1	0.062	-1.905	-0.469
2	0.073	-1.773	-0.464
3	0.083	-2.063	-0.661
4	0.094	-1.925	-0.748
5	0.107	-1.707	-0.680
6	0.123	-1.798	-0.764
7	0.135	-1.914	-0.932
8	0.148	-1.563	-0.860
9	0.163	-1.230	-0.652
10	0.181	-1.083	-0.512
11	0.203	-0.688	-0.318
12	0.296	-0.456	-0.209
13	0.404	-0.140	-0.119
14	0.652	-0.035	-0.098
15	0.671	0.261	-0.040
16	0.688	0.254	-0.145
17	0.704	0.307	-0.209
18	0.720	0.319	-0.192
19	0.741	0.199	-0.158
20	0.795	0.113	-0.150
21	0.824	0.130	-0.168
22	0.852	0.045	-0.281
23	1.000	0.725	0.725

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

ANGLE OF ATTACK = 9 FLAP DEFLECTION ANGLE = 5
FILE NUMBER 48

RESULTS OF SEAP DATA

TAP NUMBER	x/c location	Cp upper	Cp lower
1	0.062	-2.268	-0.158
2	0.073	-2.088	-0.183
3	0.083	-2.376	-0.372
4	0.094	-2.194	-0.471
5	0.107	-1.928	-0.438
6	0.123	-1.997	-0.533
7	0.135	-2.091	-0.701
8	0.148	-1.699	-0.658
9	0.163	-1.338	-0.488
10	0.181	-1.185	-0.369
11	0.203	-0.754	-0.215
12	0.295	-0.498	-0.132
13	0.404	-0.126	-0.091
14	0.652	-0.002	-0.081
15	0.671	0.322	-0.017
16	0.688	0.384	-0.286
17	0.704	0.488	-0.503
18	0.720	0.482	-0.472
19	0.741	0.316	-0.327
20	0.795	0.205	-0.276
21	0.824	0.214	-0.275
22	0.852	0.096	-0.407
23	1.000	0.683	0.683

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

ANGLE OF ATTACK = 0 FLAP DEFLECTION ANGLE = 10
FILE NUMBER 40

RESULTS OF SEAP DATA

TAP NUMBER	x/c location	Cp upper	Cp lower
1	0.060	-1.945	-0.541
2	0.071	-1.856	-0.493
3	0.081	-2.166	-0.534
4	0.091	-2.055	-0.747
5	0.102	-1.832	-0.725
6	0.116	-1.928	-0.668
7	0.128	-2.110	-0.767
8	0.140	-1.960	-0.887
9	0.151	-1.613	-0.771
10	0.165	-1.370	-0.562
11	0.180	-1.263	-0.444
12	0.199	-0.932	-0.241
13	0.278	-0.683	-0.101
14	0.399	-0.469	0.068
15	0.649	-0.428	0.141
16	0.672	-0.527	0.364
17	0.688	-0.622	0.331
18	0.704	-0.685 ?	0.317 ?
19	0.720	-0.294	0.188
20	0.844	-0.213	0.158
21	0.873	-0.072	0.127
22	0.901	0.027	0.105
23	1.001	0.170	0.170

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

ANGLE OF ATTACK = 3 FLAP DEFLECTION ANGLE = 10
FILE NUMBER 41

RESULTS OF SEAP DATA

TAP NUMBER	x/c location	Cp upper	Cp lower
1	0.060	-2.761	0.020
2	0.071	-2.588	0.006
3	0.081	-2.922	-0.063
4	0.091	-2.744	-0.245
5	0.102	-2.430	-0.265
6	0.116	-2.507	-0.252
7	0.128	-2.685	-0.353
8	0.140	-2.476	-0.469
9	0.151	-2.048	-0.400
10	0.165	-1.748	-0.252
11	0.180	-1.617	-0.168
12	0.199	-1.200	-0.033
13	0.278	-0.883	0.057
14	0.399	-0.588	0.165
15	0.649	-0.519	0.215
16	0.672	-0.566	0.400
17	0.688	-0.671	0.377
18	0.704	-0.730 ?	0.361 ?
19	0.720	-0.331	0.230
20	0.844	-0.247	0.199
21	0.873	-0.096	0.159
22	0.901	0.010	0.128
23	1.001	0.165	0.165

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

ANGLE OF ATTACK = 6 FLAP DEFLECTION ANGLE = 10
FILE NUMBER 42

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RESULTS OF SEAP DATA

TAP NUMBER	x/c location	Cp upper	Cp lower
1	0.060	-3.655	0.459
2	0.071	-3.384	0.409
3	0.081	-3.737	0.327
4	0.091	-3.476	0.178
5	0.102	-3.060	0.130
6	0.116	-3.111	0.112
7	0.128	-3.279	0.014
8	0.140	-2.999	-0.100
9	0.151	-2.483	-0.072
10	0.165	-2.128	0.028
11	0.180	-1.979	0.084
12	0.199	-1.476	0.160
13	0.278	-1.090	0.209
14	0.399	-0.707	0.262
15	0.649	-0.606	0.291
16	0.672	-0.600	0.437
17	0.688	-0.717	0.424
18	0.704	-0.771	0.407
19	0.720	-0.364	0.276
20	0.844	-0.277	0.242
21	0.873	-0.116	0.194
22	0.901	-0.003	0.153
23	1.001	0.163	0.163

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KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

ANGLE OF ATTACK = 9 FLAP DEFLECTION ANGLE = 10
FILE NUMBER 46

RESULTS OF SEAP DATA

TAP NUMBER	x/c location	Cp upper	Cp lower
1	0.060	-4.614	0.771
2	0.071	-4.232	0.711
3	0.081	-4.594	0.632
4	0.091	-4.240	0.517
5	0.102	-3.708	0.456
6	0.116	-3.724	0.417
7	0.128	-3.871	0.327
8	0.140	-3.518	0.225
9	0.151	-2.909	0.221
10	0.165	-2.492	0.272
11	0.180	-2.326	0.301
12	0.199	-1.753	0.334
13	0.278	-1.301	0.349
14	0.399	-0.833	0.359
15	0.650	-0.704	0.372
16	0.672	-0.668	0.488
17	0.688	-0.776	0.483
18	0.764	-0.816	0.467
19	0.720	-0.398	0.330
20	0.844	-0.308	0.294
21	0.873	-0.135	0.237
22	0.901	-0.016	0.185
23	1.001	0.160	0.160

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

ANGLE OF ATTACK = 0 FLAP DEFLECTION ANGLE = 15
FILE NUMBER 43

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RESULTS OF SEAP DATA

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TAP NUMBER	x/c location	Cp upper	Cp lower
1	0.073	-2.507	-0.227
2	0.085	-2.529	-0.298
3	0.098	-2.256	-0.423
4	0.114	-2.350	-0.409
5	0.128	-2.522	-0.477
6	0.142	-2.133	-0.584
7	0.157	-1.715	-0.457
8	0.175	-1.479	-0.288
9	0.197	-1.357	-0.214
10	0.222	-0.903	0.011
11	0.367	-0.781	0.073
12	0.416	-0.608	0.217
13	0.607	-0.616	0.254
14	0.632	-0.718	0.406
15	0.[illegible]	-0.750	0.418
16	0.674	-0.945	0.444
17	0.695	-1.061	0.449
18	0.715	-0.913	0.449
19	0.735	-0.269	0.248
20	0.916	-0.157	0.201
21	0.947	0.152	0.079
22	0.977	0.247	0.083
23	1.003	0.151	0.151

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KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

ANGLE OF ATTACK = 3 FLAP DEFLECTION ANGLE = 15
FILE NUMBER 44

RESULTS OF SEAP DATA

TAP NUMBER	x/c location	Cp upper	Cp lower
1	0.073	-3.224	0.190
2	0.085	-3.193	0.103
3	0.098	-2.815	-0.025
4	0.114	-2.874	-0.048
5	0.128	-3.036	-0.129
6	0.142	-2.586	-0.235
7	0.157	-2.103	-0.156
8	0.175	-1.819	-0.041
9	0.197	-1.687	0.009
10	0.222	-1.114	0.154
11	0.367	-0.959	0.193
12	0.416	-0.711	0.288
13	0.607	-0.703	0.315
14	0.631	-0.762	0.439
15	0.654	-0.787	0.454
16	0.674	-0.960	0.477
17	0.695	-1.061	0.481
18	0.715	-0.913	0.482
19	0.735	-0.280	0.275
20	0.916	-0.166	0.224
21	0.947	0.150	0.079
22	0.977	0.241	0.070
23	1.003	0.143	0.143

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

ANGLE OF ATTACK = 6 FLAP DEFLECTION ANGLE = 15
FILE NUMBER 45

RESULTS OF SEAP DATA

TAP NUMBER	x/c location	Cp upper	Cp lower
1	0.073	-4.040	0.539
2	0.085	-3.951	0.448
3	0.098	-3.454	0.328
4	0.114	-3.475	0.280
5	0.128	-3.614	0.193
6	0.142	-3.061	0.087
7	0.157	-2.491	0.121
8	0.175	-2.160	0.193
9	0.197	-2.017	0.224
10	0.222	-1.329	0.296
11	0.327	-1.144	0.316
12	0.416	-0.819	0.364
13	0.607	-0.792	0.382
14	0.631	-0.812	0.479
15	0.655	-0.840	0.497
16	0.674	-0.997	0.518
17	0.695	-1.087	0.521
18	0.715	-0.936	0.524
19	0.735	-0.292	0.311
20	0.916	-0.175	0.257
21	0.947	0.155	0.092
22	0.977	0.246	0.069
23	1.003	0.145	0.145

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

ANGLE OF ATTACK = 9   FLAP DEFLECTION ANGLE = 15
FILE NUMBER 47

RESULTS OF SEAP DATA

TAP NUMBER	x/c location	Cp upper	Cp lower
1	0.073	-4.897	0.791
2	0.085	-4.740	0.711
3	0.098	-4.113	0.608
4	0.114	-4.090	0.548
5	0.128	-4.203	0.464
6	0.142	-3.550	0.367
7	0.157	-2.891	0.365
8	0.175	-2.504	0.394
9	0.970	-2.343	0.405
10	0.222	-1.530	0.424
11	0.367	-1.310	0.427
12	0.416	-0.912	0.439
13	0.607	-0.874	0.450
14	0.632	-0.869	0.531
15	0.655	-0.898	0.554
16	0.674	-1.044	0.574
17	0.695	-1.123	0.574
18	0.715	-0.967	0.577
19	0.735	-0.304	0.356
20	0.916	-0.181	0.297
21	0.947	0.163	0.109
22	0.977	0.253	0.070
23	1.003	0.146	0.146

```
0: "DELTA P THEORETICAL PRESSURE DISTRIBUTION DATA STORER":
1: dim X[3,3,33],U[3,3,33],L[3,3,33],N$[1],Y$[1]
2: fmt 1,z,2x,f8.5
3: for I=1 to 3
4: for J=1 to 3
5: wrt 4,"ANGLE OF ATTACK=",3(J-1),"DEG"
6: wrt 4,"FLAP DEFLECTION=",5(I-1),"DEG"
7: for K=1 to 33
8: ent "X/C?",X[I,J,K]
9: wrt 4,K,X[I,J,K]
10: next K
11: ent "CHANGES?",N$
12: if cap(N$)="Y";cll 'changes'(1)
13: for K=1 to 33
14: wrt 4.1,K,X[I,J,K]
15: ent "Cp UPPER?",U[I,J,K]
16: wrt 4.1,U[I,J,K];wrt 4
17: next K
18: ent "CHANGES?",N$
19: if cap(N$)="Y";cll 'changes'(2)
20: for K=1 to 33
21: wrt 4.1,K,X[I,J,K],U[I,J,K]
22: ent "Cp LOWER?",L[I,J,K]
23: wrt 4.1,L[I,J,K];wrt 4
24: next K
25: ent "CHANGES?",N$
26: if cap(N$)="Y";cll 'changes'(3)
27: 4→r1
28: wrt r1,"ALPHA=",3(J-1),"DEG"
29: wrt r1,"DELTA FLAP=",5(I-1),"DEG"
30: wrt r1,"     X/C     Cp UPPER     Cp LOWER";wrt r1
31: for K=1 to 33
32: if cap(N$)="Y";wrt 6.1,K,X[I,J,K],U[I,J,K],L[I,J,K];wrt r1;jmp 2
33: wrt 4.1,K,X[I,J,K],U[I,J,K],L[I,J,K];wrt r1
34: next K
35: ent "GENERAL CHANGES?",Y$
36: if cap(Y$)="Y";gsb "GC"
37: if cap(N$)="Y";jmp 4
38: ent "HARD COPY OF THIS?",N$
39: if cap(N$)#"Y";jmp 3
40: 6→r1;gto 28
41: "N"→N$
42: next J
43: next I
44: trk 1;fdf 33;rcf 33,X[*],U[*],L[*]
45: stp
46: "GC":
47: "N"→Y$
48: ent "CHANGE 1) X/C? 2) Cp UPPER? 3) Cp LOWER?",A
49: cll 'changes'(A)
50: ent "MORE?",Y$
51: if cap(Y$)#"Y";ret
52: gto 47
53: "changes":
54: "N"→N$
55: ent "NUMBER?",K
56: if p1=1;ent "X/C?",X[I,J,K]
57: if p1=2;ent "Cp UPPER?",U[I,J,K]
58: if p1=3;ent "Cp LOWER?",L[I,J,K]
59: ent "MORE?",N$
60: if cap(N$)#"Y";ret
61: gto 54
*1442
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0: "SEAP -  C SUB P OUTPUTTING PROGRAM      files 34→49":
1: dim L$[80],P$[3],Y$[80],S$[10];for S=1 to 60;"*"→L$[S];next S;fxd 1
2: dim X[23],U[23],L[23],A,D;"                 "&L$→L$
3: "           "→S$
4: fmt 1,10x,f3.0,4x,"*",3f15.3
5: fmt 2,9x,"ANGLE OF ATTACK = ",f4.0,10x,"FLAP DEFLECTION ANGLE = ",f4.0
6: fmt 3,9x,"FILE NUMBER  ",f2.0
7: "PCL":ent "FILE NUMBER?",F;if F<34 or F>49;beep;gto +0
8: trk 1;rdf F;ldf F,X[*],U[*],L[*],A,D
9: "STR":wrt 6,"                   ------------------";for S=1 to 5;wrt 6;next S
10: wrt 6,"                  KANSAS UNIVERSITY FLIGHT RESEARCH LAB";wrt 6
11: wrt 6,"                          DELTA P PROJECT - PHASE I"
12: wrt 6
13: wrt 6,"                  SINGLE ELEMENT AIRFOIL PROGRAM RESULTS"
14: wrt 6;wrt 6;wrt 6;wrt 6.2,A,D;wrt 6.3,F;wrt 6;wrt 6,L$;wrt 6
15: wrt 6,S$&S$&S$&"RESULTS OF SEAP DATA"
16: wrt 6;wrt 6,L$
17: wrt 6,S$&" TAP   *"&S$&" x/c              Cp                Cp"
18: wrt 6,S$&"NUMBER *          location            upper              lower"
19: wrt 6,L$
20: wrt 6,"                *";0→B;for S=1 to 23
21: wrt 6.1,S,X[S],U[S],L[S];B+1→B
22: if B=5;0→B;wrt 6,"                 *"
23: next S;wrt 6,"                *"
24: wrt 6,L$;wrt 6;wrt 6;wrt 6
25: for S=1 to 12;wrt 6;next S
26: ent "ANOTHER FILE?",P$;if cap(P$)="Y";gto "PCL"
27: stp
*8319
```

C.3 INTERPOLATED CHANGE IN C_p BY ANGLE OF ATTACK AND FLAP DEFLECTION

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

ANGLE OF ATTACK = 0 FLAP DEFLECTION ANGLE = 0
FILE NUMBER 50

RESULTS OF SEAP DATA INTERPOLATED TO PHASE I TAP LOCATIONS

TAP NUMBER	x/c location	Cp upper	Cp lower	change in Cp
1	0.119	-1.267	-1.267	0.000
2	0.171	-0.859	-0.859	0.000
3	0.223	-0.588	-0.588	0.000
4	0.276	-0.320	-0.320	0.000
5	0.328	-0.292	-0.292	0.000
6	0.380	-0.264	-0.264	0.000
7	0.433	-0.130	-0.130	0.000
8	0.485	-0.114	-0.114	0.000
9	0.537	-0.111	-0.111	0.000
10	0.589	-0.108	-0.108	0.000
11	0.668	-0.103	-0.103	0.000
12	0.720	-0.075	-0.075	0.000
13	0.766	-0.058	-0.058	0.000

* Change in pressure coefficient represents the difference between lower and upper surface pressure coefficients

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

ANGLE OF ATTACK = 3   FLAP DEFLECTION ANGLE = 0
FILE NUMBER 51

RESULTS OF SEAP DATA INTERPOLATED TO PHASE I TAP LOCATIONS

TAP NUMBER	x/c location	Cp upper	Cp lower	change in Cp
1	0.119	-1.695	-0.841	0.854
2	0.171	-1.162	-0.574	0.587
3	0.223	-0.807	-0.376	0.431
4	0.276	-0.457	-0.184	0.273
5	0.328	-0.419	-0.164	0.255
6	0.380	-0.382	-0.145	0.237
7	0.433	-0.201	-0.055	0.145
8	0.485	-0.177	-0.049	0.127
9	0.537	-0.172	-0.048	0.124
10	0.589	-0.167	-0.047	0.120
11	0.668	-0.160	-0.045	0.115
12	0.720	-0.118	-0.034	0.084
13	0.766	-0.100	-0.018	0.082

* Change in pressure coefficient represents the difference between lower and upper surface pressure coefficients

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

ANGLE OF ATTACK = 6 FLAP DEFLECTION ANGLE = 0
FILE NUMBER 52

RESULTS OF SEAP DATA INTERPOLATED TO PHASE I TAP LOCATIONS

TAP NUMBER	x/c location	Cp upper	Cp lower	change in Cp
1	0.119	-2.193	-0.429	1.764
2	0.171	-1.474	-0.297	1.177
3	0.223	-1.031	-0.165	0.866
4	0.276	-0.602	-0.041	0.561
5	0.328	-0.557	-0.029	0.527
6	0.380	-0.511	-0.018	0.493
7	0.433	-0.285	0.031	0.316
8	0.485	-0.248	0.026	0.273
9	0.537	-0.240	0.025	0.265
10	0.589	-0.233	0.024	0.257
11	0.668	-0.222	0.022	0.245
12	0.720	-0.163	0.017	0.180
13	0.766	-0.143	0.031	0.174

* Change in pressure coefficient represents the difference between lower and upper surface pressure coefficients

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

ANGLE OF ATTACK = 0 FLAP DEFLECTION ANGLE = 5
FILE NUMBER 53

RESULTS OF SEAP DATA INTERPOLATED TO PHASE I TAP LOCATIONS

TAP NUMBER	x/c location	Cp upper	Cp lower	change in Cp*
1	0.119	-1.455	-1.104	0.352
2	0.171	-0.973	-0.809	0.165
3	0.223	-0.558	-0.401	0.156
4	0.276	-0.456	-0.310	0.147
5	0.328	-0.358	-0.216	0.142
6	0.380	-0.259	-0.120	0.139
7	0.433	-0.208	-0.068	0.140
8	0.485	-0.196	-0.054	0.142
9	0.537	-0.184	-0.040	0.144
10	0.589	-0.172	-0.025	0.147
11	0.668	-0.049	0.177	0.226
12	0.720	0.018	0.125	0.107
13	0.766	-0.043	0.052	0.094

* Change in pressure coefficient represents the difference between lower and upper surface pressure coefficients

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

ANGLE OF ATTACK = 3   FLAP DEFLECTION ANGLE = 5
FILE NUMBER 54

RESULTS OF SEAP DATA INTERPOLATED TO PHASE I TAP LOCATIONS

TAP NUMBER	x/c location	Cp upper	Cp lower	change in Cp
1	0.119	-1.606	-0.934	0.672
2	0.171	-1.078	-0.704	0.374
3	0.223	-0.600	-0.355	0.245
4	0.276	-0.482	-0.279	0.203
5	0.328	-0.360	-0.207	0.154
6	0.380	-0.236	-0.137	0.099
7	0.433	-0.169	-0.100	0.069
8	0.485	-0.152	-0.090	0.061
9	0.537	-0.135	-0.081	0.054
10	0.589	-0.118	-0.072	0.046
11	0.668	0.085	0.055	-0.030
12	0.720	0.156	-0.022	-0.178
13	0.766	0.052	-0.046	-0.097

* Change in pressure coefficient represents the difference between lower and upper surface pressure coefficients

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

ANGLE OF ATTACK = 6 FLAP DEFLECTION ANGLE = 5
FILE NUMBER 55

RESULTS OF SEAP DATA INTERPOLATED TO PHASE I TAP LOCATIONS

TAP NUMBER	x/c location	Cp upper	Cp lower	change in Cp
1	0.119	-1.777	-0.744	1.033
2	0.171	-1.164	-0.589	0.575
3	0.223	-0.638	-0.295	0.343
4	0.276	-0.506	-0.233	0.273
5	0.328	-0.362	-0.182	0.180
6	0.380	-0.210	-0.139	0.071
7	0.433	-0.128	-0.116	0.012
8	0.485	-0.106	-0.112	-0.006
9	0.537	-0.084	-0.108	-0.024
10	0.589	-0.062	-0.103	-0.042
11	0.668	0.211	-0.050	-0.261
12	0.720	0.319	-0.192	-0.511
13	0.766	0.160	-0.154	-0.314

* Change in pressure coefficient represents the difference between lower and upper surface pressure coefficients

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

ANGLE OF ATTACK = 0   FLAP DEFLECTION ANGLE = 10
FILE NUMBER 56

RESULTS OF SEAP DATA INTERPOLATED TO PHASE I TAP LOCATIONS

TAP NUMBER	x/c location	Cp upper	Cp lower	change in Cp*
1	0.119	-1.977	-0.695	1.282
2	0.171	-1.328	-0.515	0.812
3	0.223	-0.856	-0.198	0.658
4	0.276	-0.690	-0.106	0.585
5	0.328	-0.595	-0.031	0.563
6	0.380	-0.503	0.042	0.545
7	0.433	-0.464	0.078	0.542
8	0.485	-0.455	0.093	0.548
9	0.537	-0.447	0.108	0.555
10	0.589	-0.438	0.123	0.561
11	0.668	-0.511	0.328	0.839
12	0.720	-0.294	0.188	0.482
13	0.766	-0.264	0.177	0.441

* Change in pressure coefficient represents the difference between lower and upper surface pressure coefficients

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

ANGLE OF ATTACK = 3 FLAP DEFLECTION ANGLE = 10
FILE NUMBER 57

RESULTS OF SEAP DATA INTERPOLATED TO PHASE I TAP LOCATIONS

TAP NUMBER	*	x/c location	Cp upper	Cp lower	change in Cp
1	*	0.119	-2.555	-0.279	2.276
2	*	0.171	-1.697	-0.219	1.478
3	*	0.223	-1.104	-0.006	1.098
4	*	0.276	-0.893	0.054	0.947
5	*	0.328	-0.762	0.102	0.864
6	*	0.380	-0.635	0.149	0.783
7	*	0.433	-0.579	0.172	0.751
8	*	0.485	-0.564	0.183	0.747
9	*	0.537	-0.550	0.193	0.743
10	*	0.589	-0.535	0.203	0.739
11	*	0.668	-0.558	0.370	0.928
12	*	0.720	-0.331	0.231	0.562
13	*	0.766	-0.300	0.219	0.519

* Change in pressure coefficient represents the difference between lower and upper surface pressure coefficients

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

ANGLE OF ATTACK = 6 FLAP DEFLECTION ANGLE = 10
FILE NUMBER 58

RESULTS OF SEAP DATA INTERPOLATED TO PHASE I TAP LOCATIONS

TAP NUMBER	x/c location	Cp upper	Cp lower	change in Cp
1	0.119	-3.156	0.086	3.242
2	0.171	-2.070	0.050	2.119
3	0.223	-1.359	0.175	1.533
4	0.276	-1.101	0.207	1.308
5	0.328	-0.932	0.230	1.162
6	0.380	-0.767	0.253	1.020
7	0.433	-0.693	0.266	0.959
8	0.485	-0.672	0.272	0.944
9	0.537	-0.651	0.278	0.929
10	0.589	-0.630	0.284	0.914
11	0.668	-0.601	0.413	1.014
12	0.720	-0.364	0.276	0.640
13	0.766	-0.332	0.263	0.595

* Change in pressure coefficient represents the difference between lower and upper surface pressure coefficients

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA F PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

ANGLE OF ATTACK = 0 FLAP DEFLECTION ANGLE = 15
FILE NUMBER 59

RESULTS OF SEAP DATA INTERPOLATED TO PHASE I TAP LOCATIONS

TAP NUMBER	x/c location	Cp upper	Cp lower	change in Cp *
1	0.119	-2.411	-0.433	1.978
2	0.171	-1.526	-0.322	1.204
3	0.223	-0.902	0.011	0.914
4	0.276	-0.858	0.034	0.892
5	0.328	-0.814	0.056	0.870
6	0.380	-0.736	0.111	0.846
7	0.433	-0.609	0.220	0.829
8	0.485	-0.611	0.230	0.841
9	0.537	-0.613	0.240	0.853
10	0.589	-0.615	0.250	0.866
11	0.668	-0.882	0.436	1.318
12	0.720	-0.751	0.399	1.150
13	0.766	-0.250	0.240	0.490

* Change in pressure coefficient represents the difference between lower and upper surface pressure coefficients

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

ANGLE OF ATTACK = 3 FLAP DEFLECTION ANGLE = 15
FILE NUMBER 60

RESULTS OF SEAP DATA INTERPOLATED TO PHASE I TAP LOCATIONS

TAP NUMBER	x/c location	Cp upper	Cp lower	change in Cp
1	0.119	-2.932	-0.077	2.855
2	0.171	-1.882	-0.067	1.816
3	0.223	-1.113	0.154	1.267
4	0.276	-1.056	0.169	1.225
5	0.328	-1.001	0.183	1.183
6	0.380	-0.893	0.218	1.111
7	0.433	-0.710	0.290	1.001
8	0.485	-0.708	0.298	1.006
9	0.537	-0.706	0.305	1.011
10	0.589	-0.704	0.312	1.016
11	0.668	-0.908	0.470	1.378
12	0.720	-0.755	0.430	1.185
13	0.766	-0.260	0.266	0.527

* Change in pressure coefficient represents the difference between lower and upper surface pressure coefficients

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

ANGLE OF ATTACK = 6 FLAP DEFLECTION ANGLE = 15
FILE NUMBER 61

RESULTS OF SEAP DATA INTERPOLATED TO PHASE I TAP LOCATIONS

TAP NUMBER	*	x/c location	Cp upper	Cp lower	change in Cp
1	*	0.119	-3.525	0.249	3.774
2	*	0.171	-2.234	0.177	2.411
3	*	0.223	-1.327	0.296	1.623
4	*	0.276	-1.234	0.306	1.540
5	*	0.328	-1.140	0.317	1.457
6	*	0.380	-0.950	0.345	1.295
7	*	0.433	-0.817	0.366	1.182
8	*	0.485	-0.809	0.371	1.180
9	*	0.537	-0.802	0.375	1.177
10	*	0.589	-0.795	0.380	1.175
11	*	0.668	-0.947	0.511	1.459
12	*	0.720	-0.775	0.471	1.246
13	*	0.766	-0.272	0.302	0.574

* Change in pressure coefficient represents the difference between lower and upper surface pressure coefficients

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

ANGLE OF ATTACK = 9 FLAP DEFLECTION ANGLE = 10
FILE NUMBER 62

RESULTS OF SEAP DATA INTERPOLATED TO PHASE I TAP LOCATIONS

TAP NUMBER	x/c location	Cp upper	Cp lower	change in Cp
1	0.119	-3.761	0.395	4.155
2	0.171	-2.426	0.284	2.709
3	0.223	-1.616	0.339	1.954
4	0.276	-1.312	0.349	1.661
5	0.328	-1.108	0.353	1.461
6	0.380	-0.906	0.357	1.264
7	0.433	-0.816	0.361	1.176
8	0.485	-0.789	0.363	1.152
9	0.537	-0.762	0.366	1.128
10	0.589	-0.735	0.369	1.104
11	0.668	-0.675	0.467	1.141
12	0.720	-0.398	0.330	0.728
13	0.766	-0.365	0.317	0.681

* Change in pressure coefficient represents the difference between lower and upper surface pressure coefficients

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DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

ANGLE OF ATTACK = 9 FLAP DEFLECTION ANGLE = 15
FILE NUMBER 63

RESULTS OF SEAP DATA INTERPOLATED TO PHASE I TAP LOCATIONS

TAP NUMBER	x/c location	Cp upper	Cp lower	change in Cp
1	0.119	-4.130	0.518	4.648
2	0.171	-2.590	0.388	2.978
3	0.223	-1.528	0.424	1.953
4	0.276	-1.448	0.425	1.873
5	0.328	-1.369	0.426	1.795
6	0.380	-1.204	0.430	1.635
7	0.433	-0.909	0.440	1.349
8	0.485	-0.898	0.443	1.341
9	0.537	-0.888	0.446	1.334
10	0.589	-0.878	0.449	1.327
11	0.668	-0.998	0.568	1.566
12	0.720	-0.801	0.522	1.323
13	0.766	-0.283	0.346	0.629

* Change in pressure coefficient represents the difference between lower and upper surface pressure coefficients

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

ANGLE OF ATTACK = 9 FLAP DEFLECTION ANGLE = 5
FILE NUMBER 64

RESULTS OF SEAP DATA INTERPOLATED TO PHASE I TAP LOCATIONS

TAP NUMBER	x/c location	Cp upper	Cp lower	change in Cp*
1	0.119	-1.980	-0.509	1.471
2	0.171	-1.270	-0.435	0.835
3	0.223	-0.698	-0.197	0.501
4	0.276	-0.551	-0.149	0.402
5	0.328	-0.385	-0.120	0.266
6	0.380	-0.208	-0.100	0.108
7	0.433	-0.112	-0.090	0.022
8	0.485	-0.086	-0.088	-0.002
9	0.537	-0.060	-0.086	-0.026
10	0.589	-0.034	-0.084	-0.050
11	0.668	0.271	-0.027	-0.298
12	0.720	0.482	-0.472	-0.954
13	0.766	0.265	-0.303	-0.568

* Change in pressure coefficient represents the difference between lower and upper surface pressure coefficients

```
0: "SEAP INTERPOL. PROG.":
1: dim X[13],U[13],L[13],C[13],A,D;dim G[23],H[23],I[23],O,Q
2: dim E[13,16],A[16],D[16];dim B[4,4],P,X
3: .119→X[1];.171→X[2];.223→X[3];.276→X[4];.328→X[5];.38→X[6];.433→X[7]
4: .485→X[8];.537→X[9];.589→X[10];.668→X[11];.72→X[12];.766→X[13]
5: trk 1;for F=34 to 48
6: ldf F,G[*],H[*],I[*],O,Q
7: for I=1 to 13
8: for J=1 to 22
9: if X[I]#G[J];gto 11
10: H[J]→U[I];I[J]→L[I];gto 15
11: if not (X[I]>G[J] and X[I]<G[J+1]);gto 16
12: (X[I]-G[J])/(G[J+1]-G[J])→Z
13: Z(H[J+1]-H[J])+H[J]→U[I]
14: Z(I[J+1]-I[J])+I[J]→L[I]
15: L[I]-U[I]→C[I]→E[I,F-33]
16: next J
17: next I
18: O→A[F-33]→A;Q→D[F-33]→D
19: rcf F+16,X[*],U[*],L[*],C[*],A,D
20: next F
21: for T=1 to 13;T→P;X[T]→X
22: for S=1 to 16
23: E[T,S]→B[D[S]/5+1,A[S]/3+1]
24: next S
25: fdf T+65;rcf T+65,B[*],P,X
26: next T
*24010
```

```
0: "SEAP - DELTA C SUB P OUTPUTTING PROGRAM      files 50→65":
1: dim L$[80],P$[3],Y$[80],S$[10];for S=1 to 60;"*"→L$[S];next S;fxd 1
2: dim X[13],U[13],L[13],C[13],A,D;"            "&L$→L$
3: "           "→S$
4: fmt 1,10x,f3.0,4x,"*",4f12.3
5: fmt 2,9x,"ANGLE OF ATTACK = ",f4.0,10x,"FLAP DEFLECTION ANGLE = ",f4.0
6: fmt 3,9x,"FILE NUMBER  ",f2.0
7: "PCL":ent "FILE NUMBER?",F;if F>65 or F<50;gto +0
8: trk 1;fdf F;ldf F,X[*],U[*],L[*],C[*],A,D
9: "STR":wrt 6,"                   ------------------";for S=1 to 5;wrt 6;next S
10: wrt 6,"                  KANSAS UNIVERSITY FLIGHT RESEARCH LAB";wrt 6
11: wrt 6,"                        DELTA P PROJECT - PHASE I"
12: wrt 6
13: wrt 6,"                  SINGLE ELEMENT AIRFOIL PROGRAM RESULTS"
14: wrt 6;wrt 6;wrt 6;wrt 6.2,A,D;wrt 6.3,F;wrt 6;wrt 6,L$;wrt 6
15: wrt 6,S$&"RESULTS OF SEAP DATA INTERPOLATED TO PHASE I TAP LOCATIONS"
16: wrt 6;wrt 6,L$
17: wrt 6,S$&" TAP    *        x/c         Cp          Cp        change in"
18: wrt 6,S$&"NUMBER *     location      upper       lower          Cp"
19: wrt 6,L$
20: for S=1 to 13
21: wrt 6.1,S,X[S],U[S],L[S],C[S];wrt 6,"                    *";next S
22: wrt 6,L$;wrt 6;wrt 6;wrt 6
23: wrt 6,S$&"*  Change in pressure coefficient represents the difference"
24: wrt 6,S$&"   between lower and upper surface pressure coefficients"
25: for S=1 to 12;wrt 6;next S
26: ent "another file?",P$;if cap(P$)≠"N";gto "PCL"
27: stp
*13077
```

C.4 INTERPOLATED CHANGE IN C_p BY TAP LOCATION

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

TAP NUMBER 1 FILE NUMBER 66

TAP x/c LOCATION 0.119

CHANGE IN PRESSURE COEFFICIENT
INTERPOLATED

FLAP DEFLECTION	ALPHA-ANGLE OF ATTACK (degrees) 0	3	6	9
0.0	0.000	0.854	1.764	0.000
5.0	0.352	0.672	1.033	1.471
10.0	1.282	2.276	3.242	4.155
15.0	1.978	2.855	3.774	4.648

* Results of SEAP data interpolated to phase I tap locations

* Change in pressure coefficient represents the difference between lower and upper surface pressure coefficients

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

TAP NUMBER 2 FILE NUMBER 67

TAP x/c LOCATION 0.171

CHANGE IN PRESSURE COEFFICIENT
INTERPOLATED

FLAP DEFLECTION	ALPHA-ANGLE OF ATTACK (degrees) 0	3	6	9
0.0	0.000	0.587	1.177	0.000
5.0	0.165	0.374	0.575	0.835
10.0	0.812	1.478	2.119	2.709
15.0	1.204	1.816	2.411	2.978

* Results of SEAP data interpolated to phase I tap locations

* Change in pressure coefficient represents the difference between lower and upper surface pressure coefficients

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

TAP NUMBER 3 FILE NUMBER 68

TAP x/c LOCATION 0.223

CHANGE IN PRESSURE COEFFICIENT
INTERPOLATED

FLAP DEFLECTION	ALPHA-ANGLE OF ATTACK (degrees) 0	3	6	9
0.0	0.000	0.431	0.866	0.000
5.0	0.156	0.245	0.343	0.501
10.0	0.658	1.098	1.533	1.954
15.0	0.914	1.267	1.623	1.953

* Results of SEAP data interpolated to phase I tap locations

* Change in pressure coefficient represents the difference between lower and upper surface pressure coefficients

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

TAP NUMBER 4 FILE NUMBER 69

TAP x/c LOCATION 0.276

CHANGE IN PRESSURE COEFFICIENT
INTERPOLATED

FLAP DEFLECTION	ALPHA-ANGLE OF ATTACK (degrees) 0	3	6	9
0.0	0.000	0.273	0.561	0.000
5.0	0.147	0.203	0.273	0.402
10.0	0.585	0.947	1.308	1.661
15.0	0.892	1.225	1.540	1.873

* Results of SEAP data interpolated to phase I tap locations

* Change in pressure coefficient represents the difference between lower and upper surface pressure coefficients

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

TAP NUMBER 5 FILE NUMBER 70

TAP x/c LOCATION 0.328

CHANGE IN PRESSURE COEFFICIENT
INTERPOLATED

FLAP DEFLECTION	ALPHA-ANGLE OF ATTACK (degrees) 0	3	6	9
0.0	0.000	0.255	0.527	0.000
5.0	0.142	0.154	0.180	0.266
10.0	0.563	0.864	1.162	1.461
15.0	0.870	1.183	1.457	1.795

* Results of SEAP data interpolated to phase I tap locations

* Change in pressure coefficient represents the difference between lower and upper surface pressure coefficients

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

TAP NUMBER 6 FILE NUMBER 71

TAP x/c LOCATION 0.380

CHANGE IN PRESSURE COEFFICIENT
INTERPOLATED

FLAP DEFLECTION	ALPHA-ANGLE OF ATTACK (degrees) 0	3	6	9
0.0	0.000	0.237	0.493	0.000
5.0	0.139	0.099	0.071	0.108
10.0	0.545	0.783	1.020	1.264
15.0	0.846	1.111	1.295	1.635

* Results of SEAP data interpolated to phase I tap locations

* Change in pressure coefficient represents the difference between lower and upper surface pressure coefficients

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

TAP NUMBER 7 FILE NUMBER 72

TAP x/c LOCATION 0.433

CHANGE IN PRESSURE COEFFICIENT
INTERPOLATED

FLAP DEFLECTION	ALPHA-ANGLE OF ATTACK (degrees) 0	3	6	9
0.0	0.000	0.145	0.316	0.000
5.0	0.140	0.069	0.012	0.022
10.0	0.542	0.751	0.959	1.176
15.0	0.829	1.001	1.182	1.349

* Results of SEAP data interpolated to phase I tap locations

* Change in pressure coefficient represents the difference between lower and upper surface pressure coefficients

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

TAP NUMBER 8 FILE NUMBER 73

TAP x/c LOCATION 0.485

CHANGE IN PRESSURE COEFFICIENT
INTERPOLATED

FLAP DEFLECTION	ALPHA-ANGLE OF ATTACK (degrees) 0	3	6	9
0.0	0.000	0.127	0.273	0.000
5.0	0.142	0.061	-0.006	-0.002
10.0	0.548	0.747	0.944	1.152
15.0	0.841	1.006	1.180	1.341

* Results of SEAP data interpolated to phase I tap locations

* Change in pressure coefficient represents the difference between lower and upper surface pressure coefficients

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

TAP NUMBER 9 FILE NUMBER 74

TAP x/c LOCATION 0.537

CHANGE IN PRESSURE COEFFICIENT
INTERPOLATED

FLAP DEFLECTION	ALPHA-ANGLE OF ATTACK (degrees) 0	3	6	9
0.0	0.000	0.124	0.265	0.000
5.0	0.144	0.054	-0.024	-0.026
10.0	0.555	0.743	0.929	1.128
15.0	0.853	1.011	1.177	1.334

* Results of SEAP data interpolated to phase I tap locations

* Change in pressure coefficient represents the difference between lower and upper surface pressure coefficients

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

TAP NUMBER 10 FILE NUMBER 75

TAP x/c LOCATION 0.589

CHANGE IN PRESSURE COEFFICIENT
INTERPOLATED

FLAP DEFLECTION	ALPHA-ANGLE OF ATTACK (degrees) 0	3	6	9
0.0	0.000	0.120	0.257	0.000
5.0	0.147	0.046	-0.042	-0.050
10.0	0.561	0.739	0.914	1.104
15.0	0.866	1.016	1.175	1.327

* Results of SEAP data interpolated to phase I tap locations

* Change in pressure coefficient represents the difference between lower and upper surface pressure coefficients

KANSAS UNIVERSITY FLIGHT RESEARCH LAB

DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

TAP NUMBER 11 FILE NUMBER 76

TAP x/c LOCATION 0.668

CHANGE IN PRESSURE COEFFICIENT
INTERPOLATED

FLAP DEFLECTION	ALPHA-ANGLE OF ATTACK (degrees) 0	3	6	9
0.0	0.000	0.115	0.245	0.000
5.0	0.226	-0.030	-0.261	-0.298
10.0	0.839	0.928	1.014	1.141
15.0	1.318	1.378	1.459	1.566

* Results of SEAP data interpolated to phase I tap locations

* Change in pressure coefficient represents the difference between lower and upper surface pressure coefficients

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DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

TAP NUMBER 12　　　　FILE NUMBER 77

TAP x/c LOCATION 0.720

CHANGE IN PRESSURE COEFFICIENT
INTERPOLATED

FLAP DEFLECTION	ALPHA-ANGLE OF ATTACK (degrees) 0	3	6	9
0.0	0.000	0.084	0.180	0.000
5.0	0.107	-0.178	-0.511	-0.954
10.0	0.482	0.562	0.640	0.728
15.0	1.150	1.185	1.246	1.323

* Results of SEAP data interpolated to phase I tap locations

* Change in pressure coefficient represents the difference between lower and upper surface pressure coefficients

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DELTA P PROJECT - PHASE I

SINGLE ELEMENT AIRFOIL PROGRAM RESULTS

TAP NUMBER 13 FILE NUMBER 78

TAP x/c LOCATION 0.766

CHANGE IN PRESSURE COEFFICIENT
INTERPOLATED

FLAP DEFLECTION	ALPHA-ANGLE OF ATTACK (degrees) 0	3	6	9
0.0	0.000	0.082	0.174	0.000
5.0	0.094	-0.097	-0.314	-0.568
10.0	0.441	0.519	0.595	0.681
15.0	0.490	0.527	0.574	0.629

* Results of SEAP data interpolated to phase 1 tap locations

* Change in pressure coefficient represents the difference between lower and upper surface pressure coefficients

```
0: "SEAP DATA OUTPUTTING PROGRAM   specific x/c files 66→78":
1: dim L$[80],P$[3],Y$[80],S$[5],T$[10];for S=1 to 75;"*"→L$[S];next S;fxd 1
2: dim B[4,4],P,X;"    "→S$;"          "→T$
3: fmt 3,z,f12.2,2x;fmt 5,5x,"TAP NUMBER ",f2.0,35x,"FILE NUMBER ",f3.0
4: fmt 4,z,6x,f5.1,2x,"*",2x;fmt 6,5x,"TAP x/c LOCATION ",f6.3
5: T$&"0"&T$&"   3"&T$&"  6"&T$&"   9"→Y$
6: "PCL":ent "FILE NUMBER?",F;if F>78 or F<66;gto +0
7: trk 1;idf F;ldf F,B[*],P,X
8: "STR":wrt 6,T$&T$&T$&"-----------------";for S=1 to 3;wrt 6;next S
9: wrt 6,T$&"          KANSAS UNIVERSITY FLIGHT RESEARCH LAB";wrt 6
10: wrt 6,T$&T$&"     DELTA P PROJECT - PHASE I"
11: wrt 6
12: wrt 6,T$&"           SINGLE ELEMENT AIRFOIL PROGRAM RESULTS"
13: wrt 6;wrt 6;wrt 6;wrt 6;wrt 6.5,P,F;wrt 6;wrt 6.6,X;wrt 6;wrt 6;wrt 6
14: wrt 6;wrt 6,S$&L$;wrt 6
15: wrt 6,T$&T$&"     CHANGE IN PRESSURE COEFFICIENT"
16: wrt 6,T$&T$&T$&"    INTERPOLATED"
17: wrt 6;wrt 6,S$&L$
18: wrt 6,"        FLAP    *             ALPHA-ANGLE OF ATTACK (degrees)"
19: wrt 6,"    DEFLECTION*   ",Y$
20: wrt 6,S$&L$;wrt 6,T$&"    *"
21: for I=1 to 4;(I-1)5→C;wrt 6.4,C;for J=1 to 4
22: wrt 6.3,B[I,J];next J;wrt 6;wrt 6,T$&"    *"
23: next I
24: wrt 6,S$&L$;wrt 6;wrt 6;wrt 6;wrt 6;wrt 6;wrt 6
25: wrt 6,T$&"*   Results of SEAP data interpolated to phase I tap lacations"
26: wrt 6
27: wrt 6,T$&"*   Change in pressure coefficient represents the difference"
28: wrt 6,T$&"    between lower and upper surface pressure coefficients"
29: for S=1 to 16
30: wrt 6;next S;ent "ANOTHER FILE?",P$;if cap(P$)="Y";gto "PCL"
31: end
*8226
```

C.5 GRAPHICAL OUTPUT--FLAP DEFLECTION SENSITIVITY

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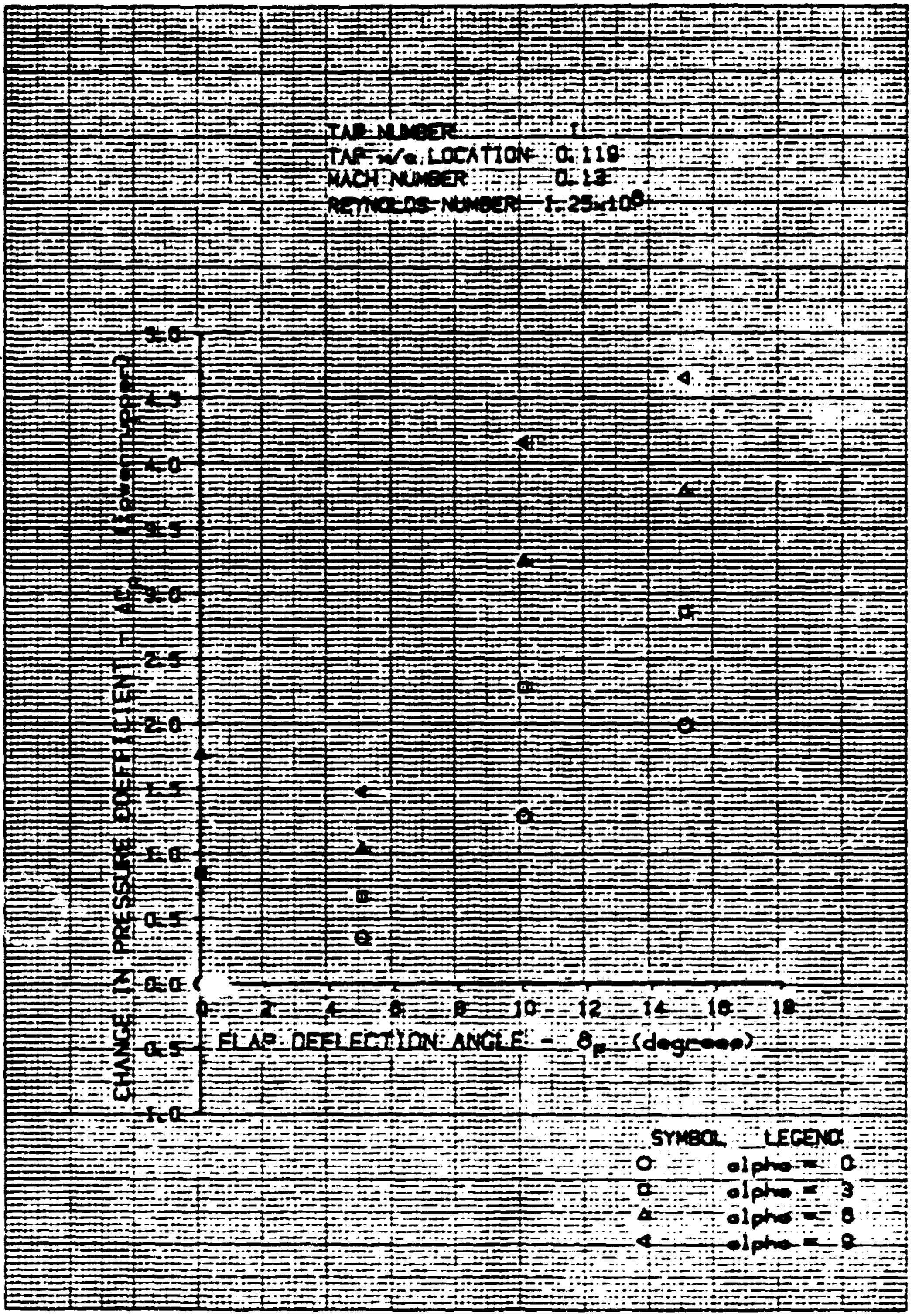
NOTE: THEORETICAL DATA INTERPOLATED TO SPECIFIC TAP LOCATIONS



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CALC	P. FINN	8-81	REVISED	DATE	FIGURE C.1 SEAP THEORETICAL CHANGE IN PRESSURE COEFFICIENTS - FLAP DEFLECTION SENSITIVITY	DATE 5-8-81
CHECK	R. HRABAK	8-81				
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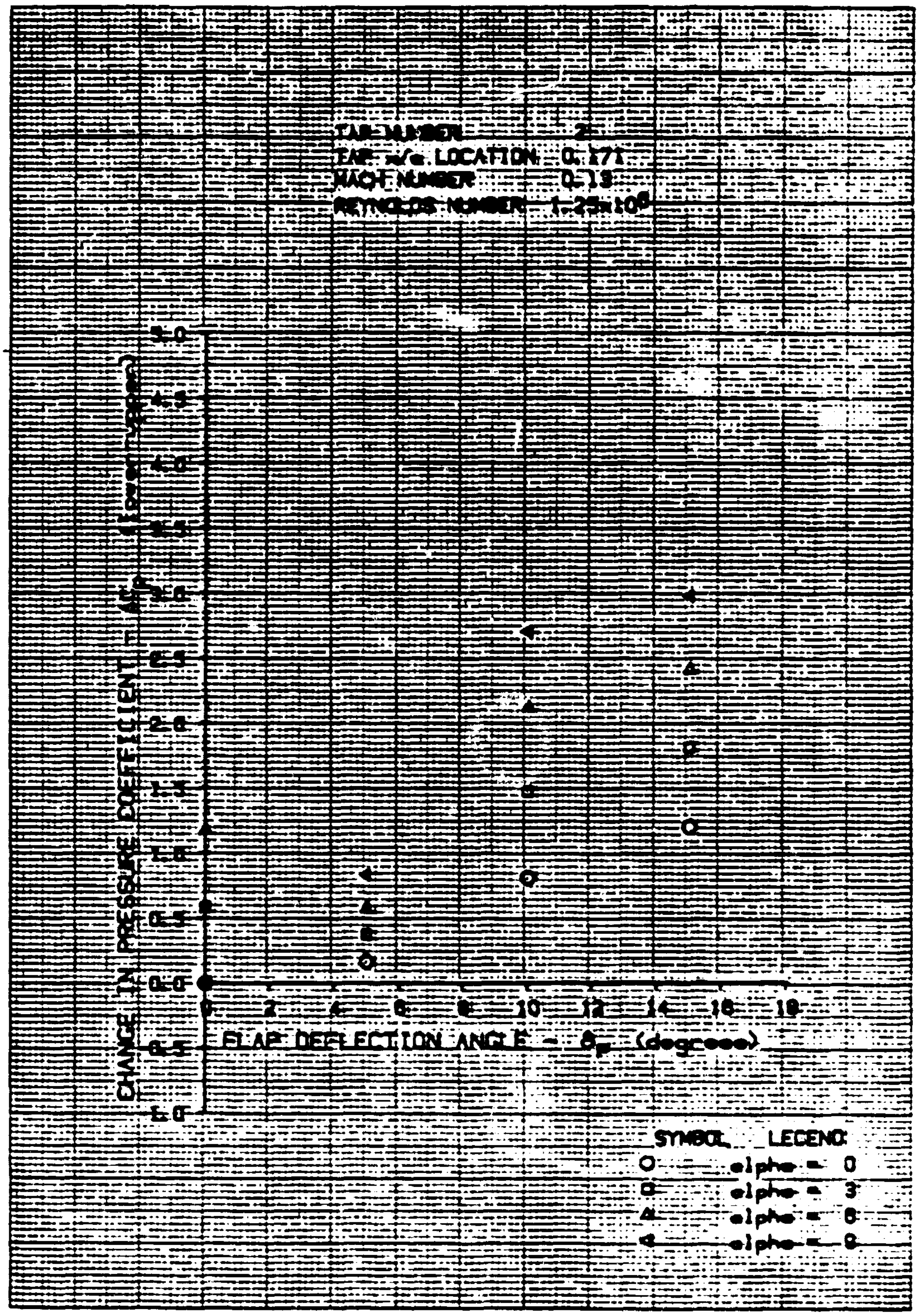
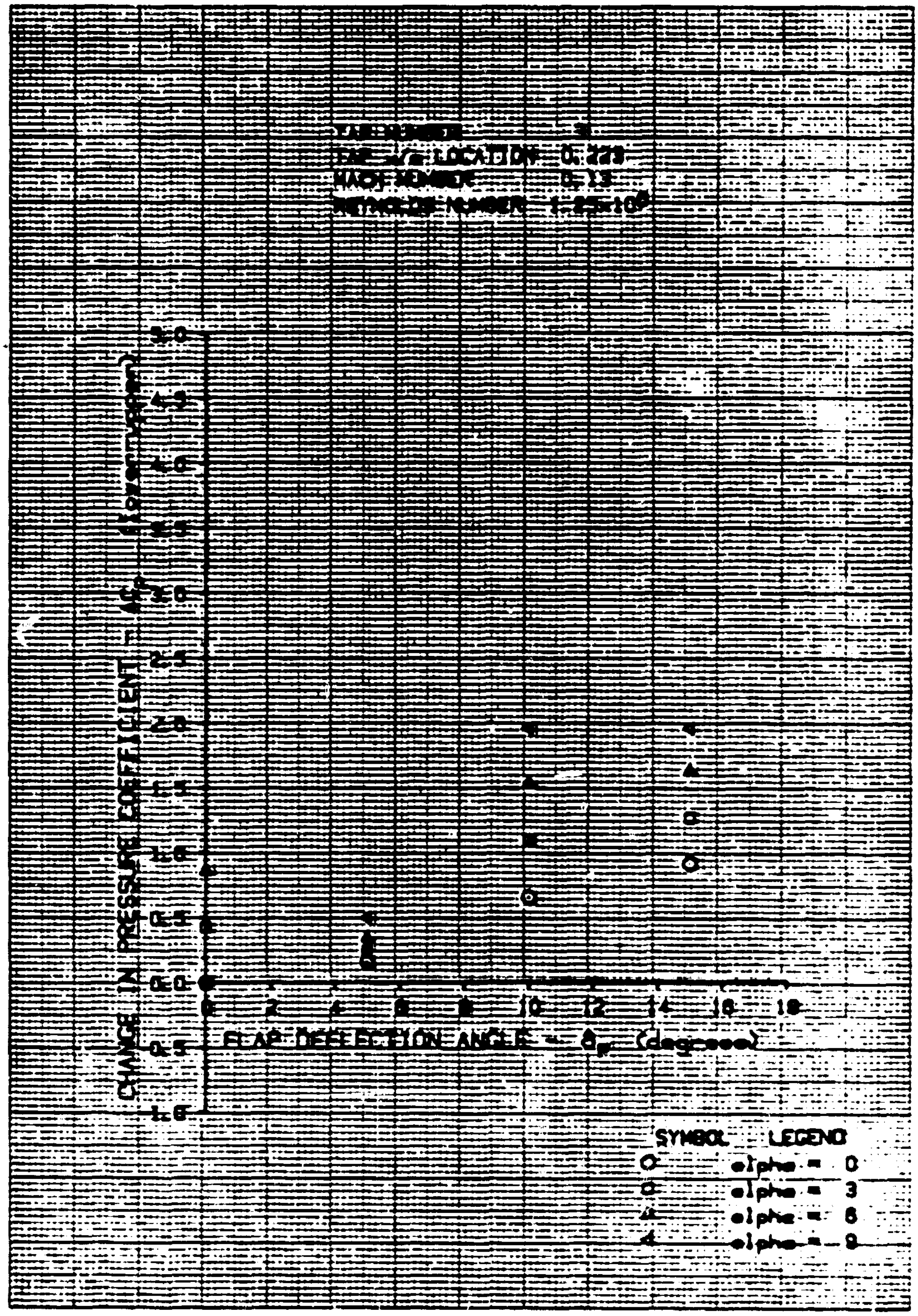
APPD					UNIVERSITY OF KANSAS	PAGE 146

NOTE: THEORETICAL DATA INTERPOLATED TO SPECIFIC TAP LOCATIONS



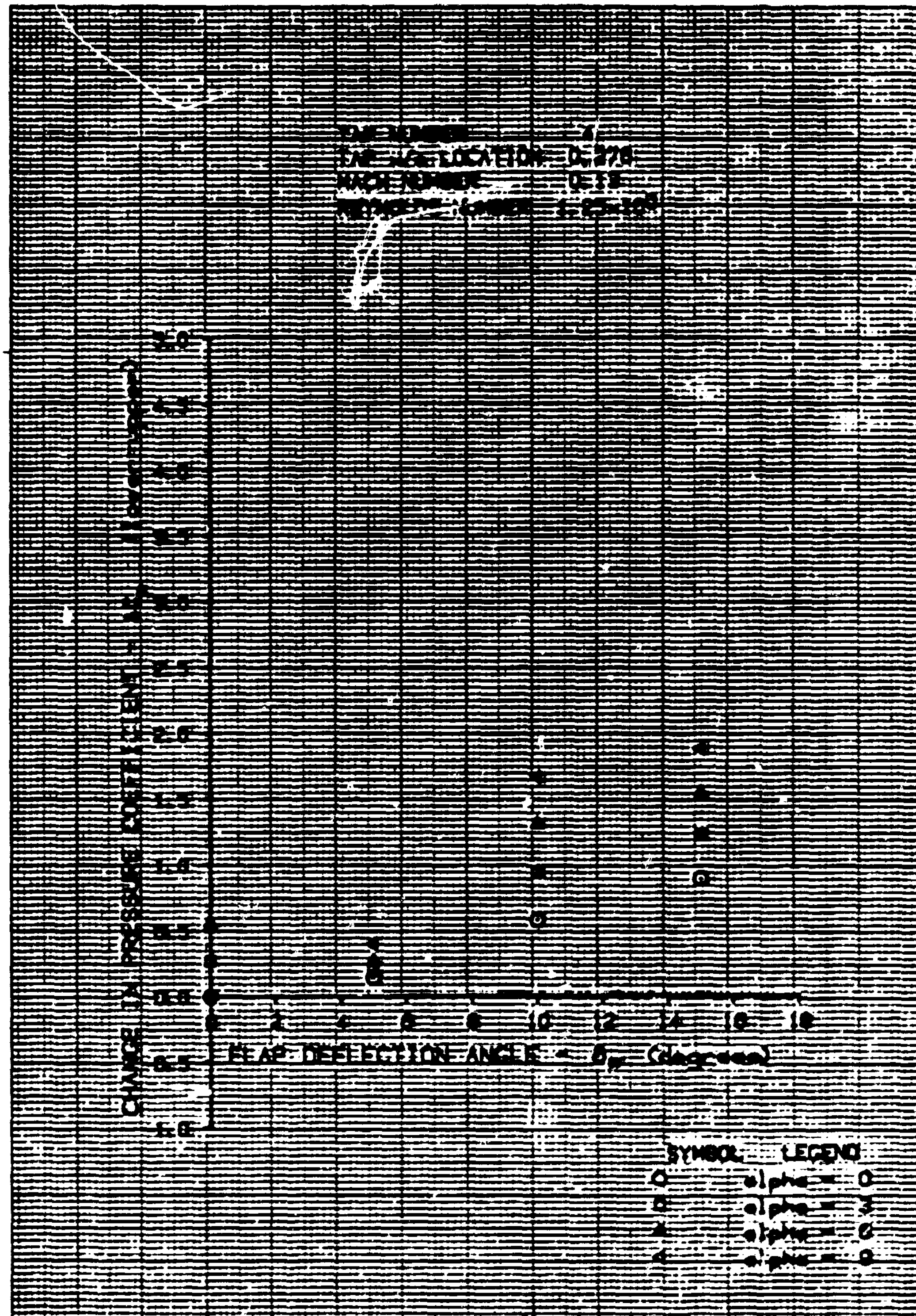
CALC	P. FINN	8-81	REVISED	DATE	FIGURE C. 2 SEAP THEORETICAL CHANGE IN PRESSURE COEFFICIENTS - FLAP DEFLECTION SENSITIVITY		DATE 5-8-81
CHECK	R. HRABAK	8-81					
APPD							
APPD					UNIVERSITY OF KANSAS		PAGE 147

NOTE: THEORETICAL DATA INTERPOLATED TO SPECIFIC TAP LOCATIONS



CALC	P. FINN	8-81	REVISED	DATE	FIGURE C.3 SEAP THEORETICAL CHANGE IN PRESSURE COEFFICIENTS - FLAP DEFLECTION SENSITIVITY	DATE 5-8-81
CHECK	R. HRABAK	8-81				
APPD						
APPD					UNIVERSITY OF KANSAS	PAGE 148

NOTE: THEORETICAL DATA INTERPOLATED TO SPECIFIC TAP LOCATIONS



CALC	P. FINN	8-81	REVISED	DATE	FIGURE C. 4 SEAP THEORETICAL CHANGE IN PRESSURE COEFFICIENTS - FLAP DEFLECTION SENSITIVITY	DATE 5-8-81
CHECK	R HRABAK	8-81				
APPD						
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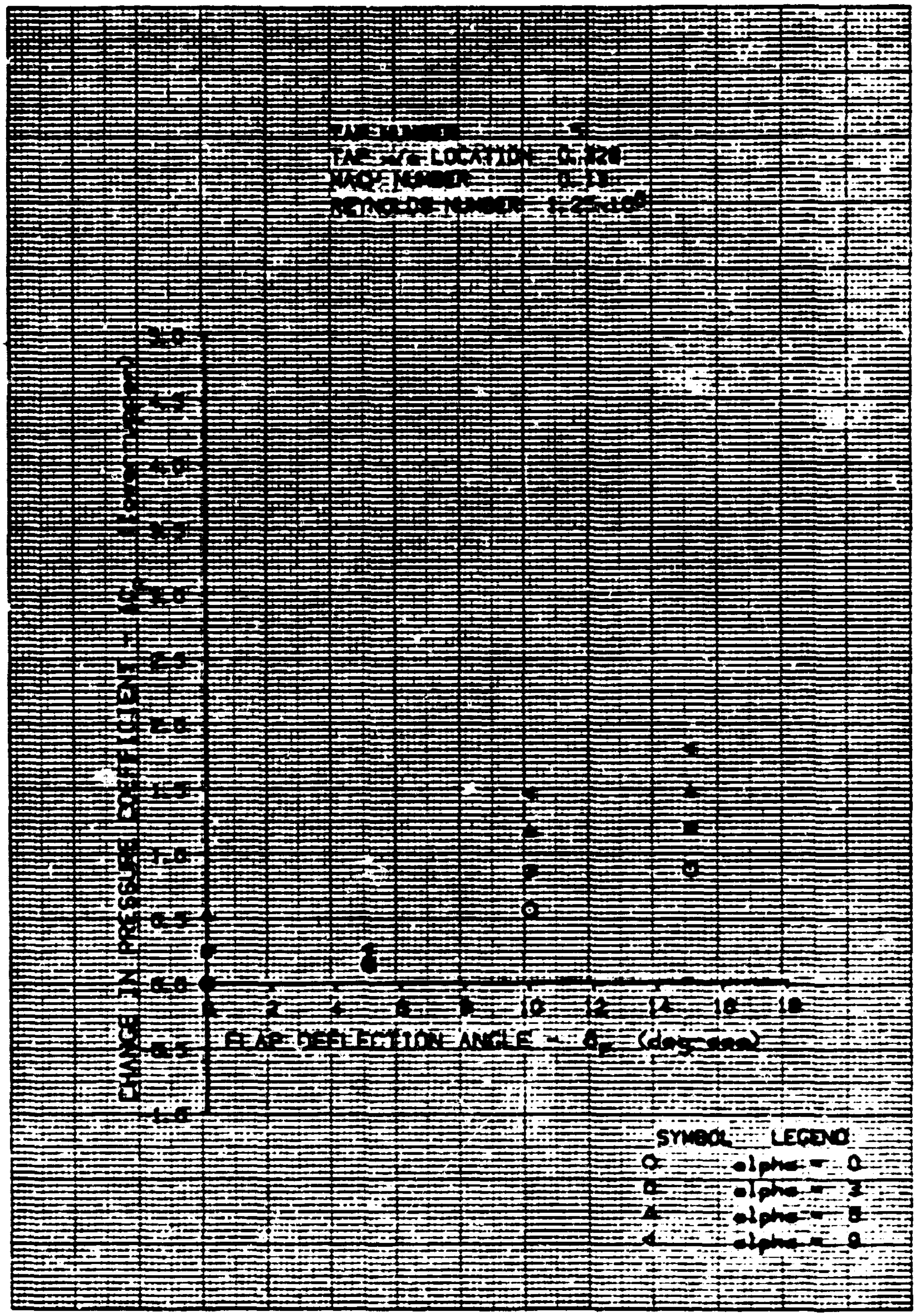
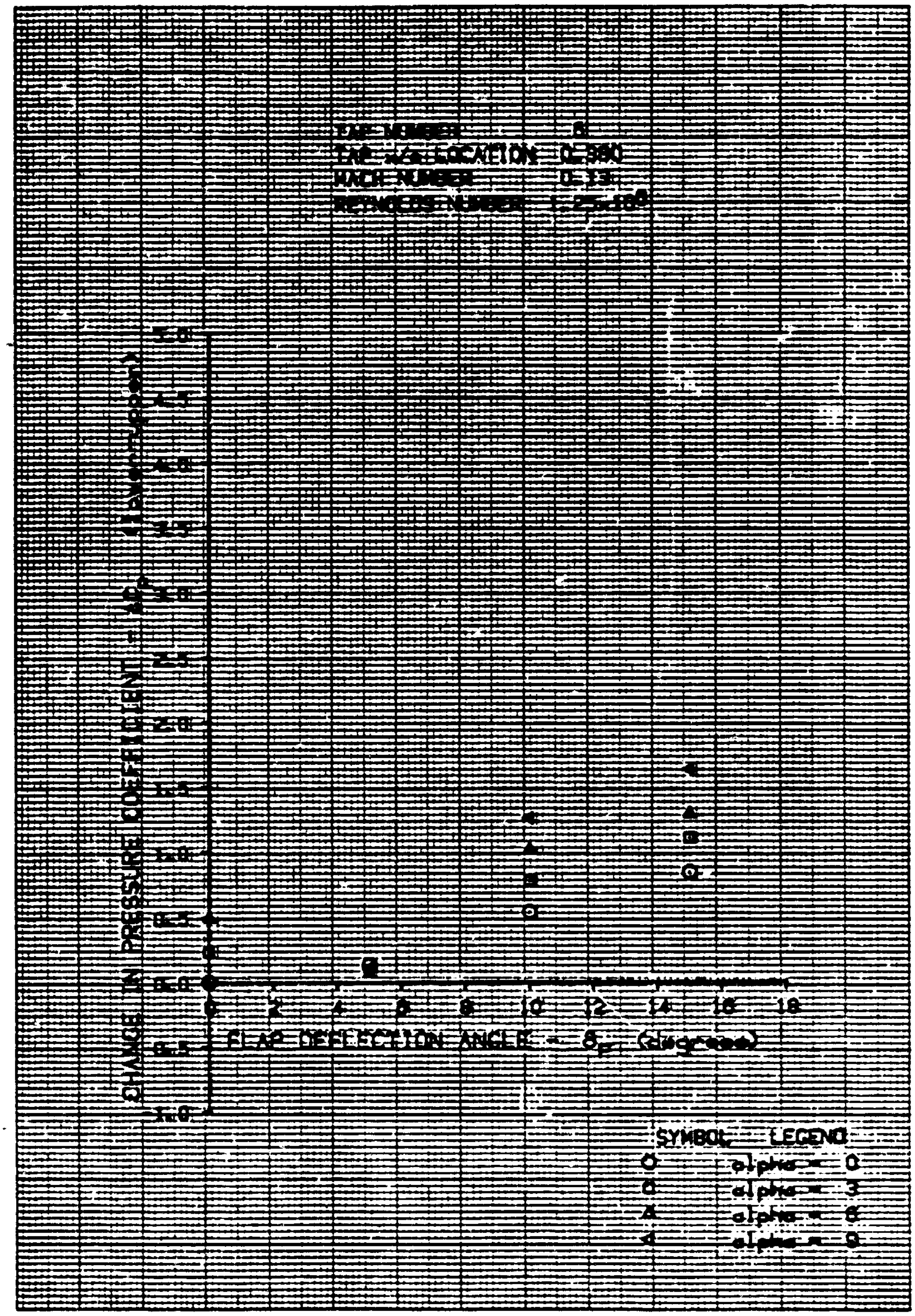
NOTE: THEORETICAL DATA INTERPOLATED TO SPECIFIC TAP LOCATIONS



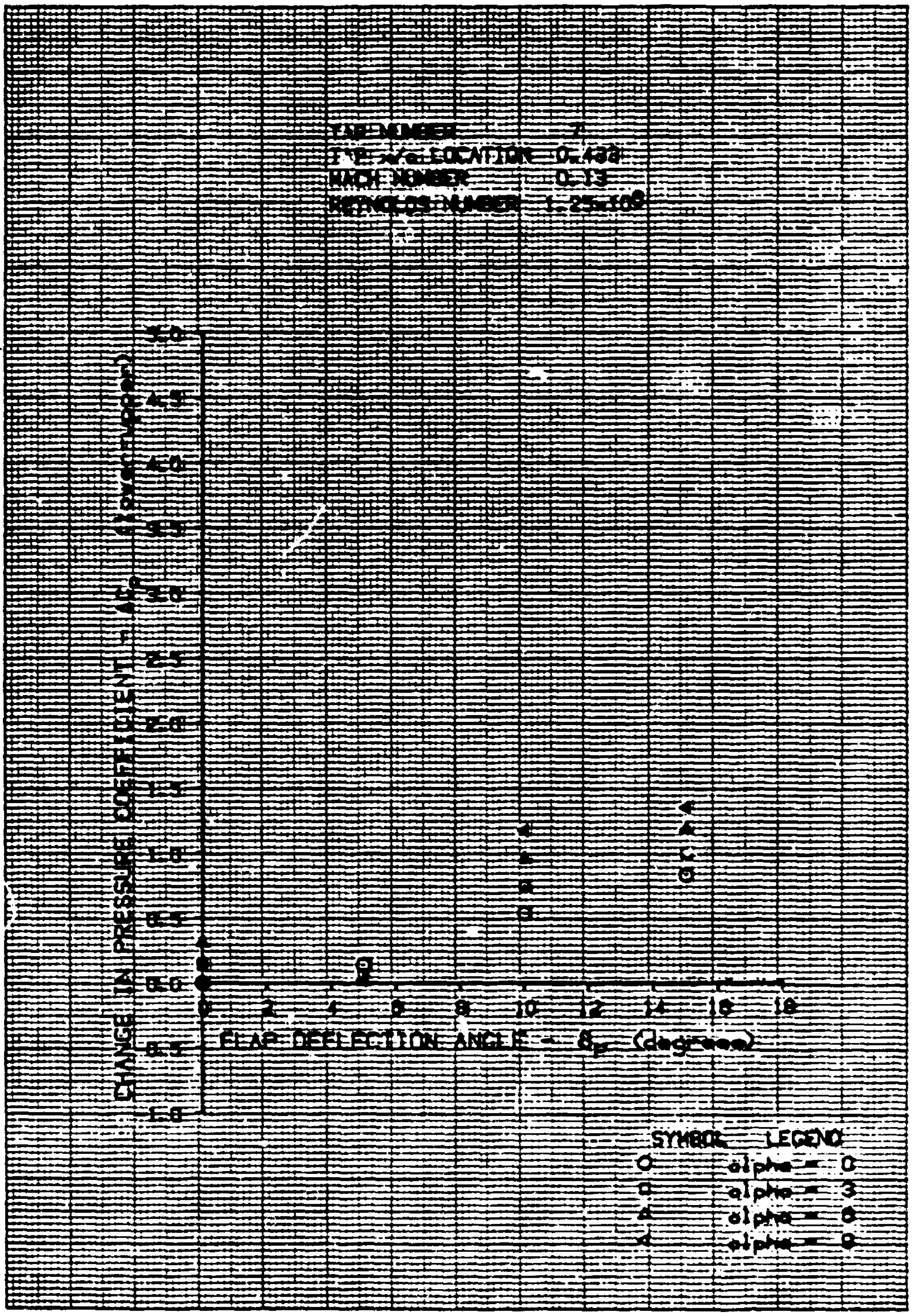
CALC	P. FINN	8-81	REVISED	DATE	FIGURE C.5 SEAP THEORETICAL CHANGE IN PRESSURE COEFFICIENTS - FLAP DEFLECTION SENSITIVITY	DATE 5-8-81
CHECK	R. HRABAK	8-81				
APPD						
APPD					UNIVERSITY OF KANSAS	PAGE 150

NOTE: THEORETICAL DATA INTERPOLATED TO SPECIFIC TAP LOCATIONS



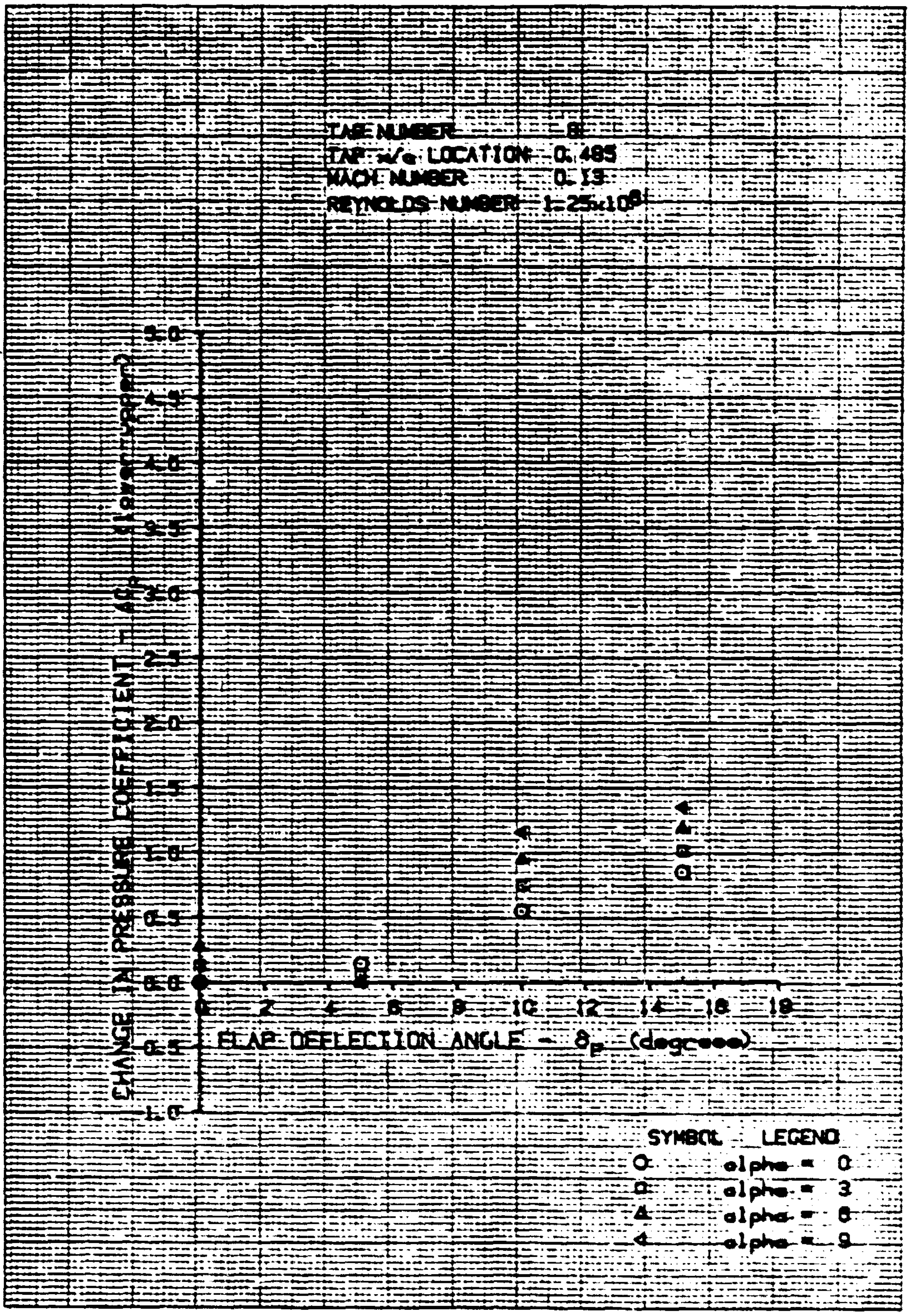
CALC	P. FINN	8-81	REVISED	DATE	FIGURE C. 6 SEAP THEORETICAL CHANGE IN PRESSURE COEFFICIENTS - FLAP DEFLECTION SENSITIVITY	DATE 5-8-81
CHECK	R. HRABAK	8-81				
APPD						
APPD					UNIVERSITY OF KANSAS	PAGE 151

NOTE: THEORETICAL DATA INTERPOLATED TO SPECIFIC TAP LOCATIONS



CALC	P. FINN	8-81	REVISED	DATE	FIGURE C.7 SEAP THEORETICAL CHANGE IN PRESSURE COEFFICIENTS - FLAP DEFLECTION SENSITIVITY
CHECK	R. HRABAK	8-81			DATE 5-8-81
APPD					
APPD					
					UNIVERSITY OF KANSAS

NOTE: THEORETICAL DATA INTERPOLATED TO SPECIFIC TAP LOCATIONS



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CALC	P. FINN	8-81	REVISED	DATE	FIGURE C.8 SEAP THEORETICAL CHANGE IN PRESSURE COEFFICIENTS - FLAP DEFLECTION SENSITIVITY	DATE 5-8-81
CHECK	R. HAAGAK	8-81				
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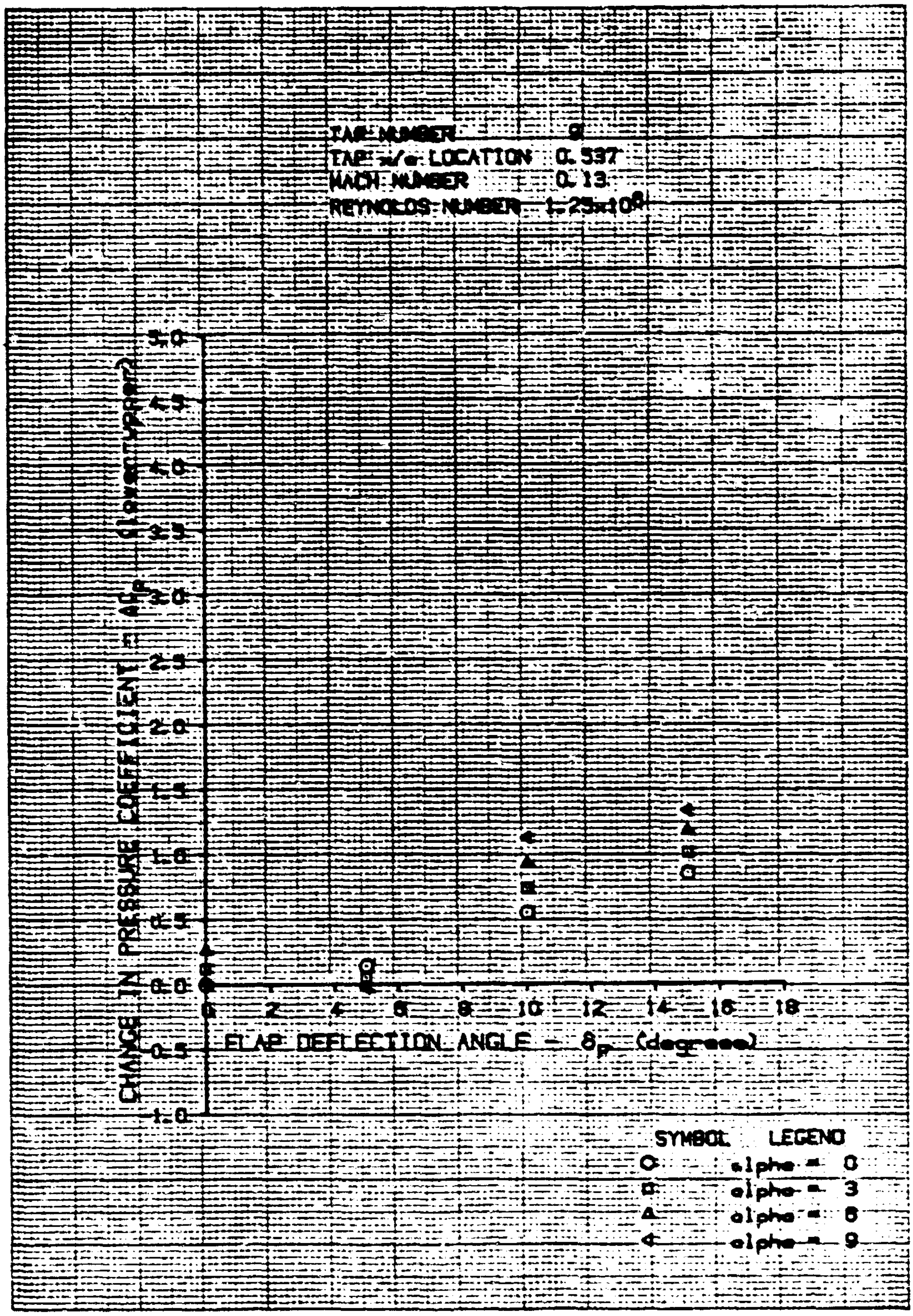
NOTE: THEORETICAL DATA INTERPOLATED TO SPECIFIC TAP LOCATIONS



CALC	P. FINN	8-81	REVISED	DATE	FIGURE C.9 SEAP THEORETICAL CHANGE IN PRESSURE COEFFICIENTS - FLAP DEFLECTION SENSITIVITY	DATE 5-8-81
CHECK	R. HAABAK	8-81				
APPD						
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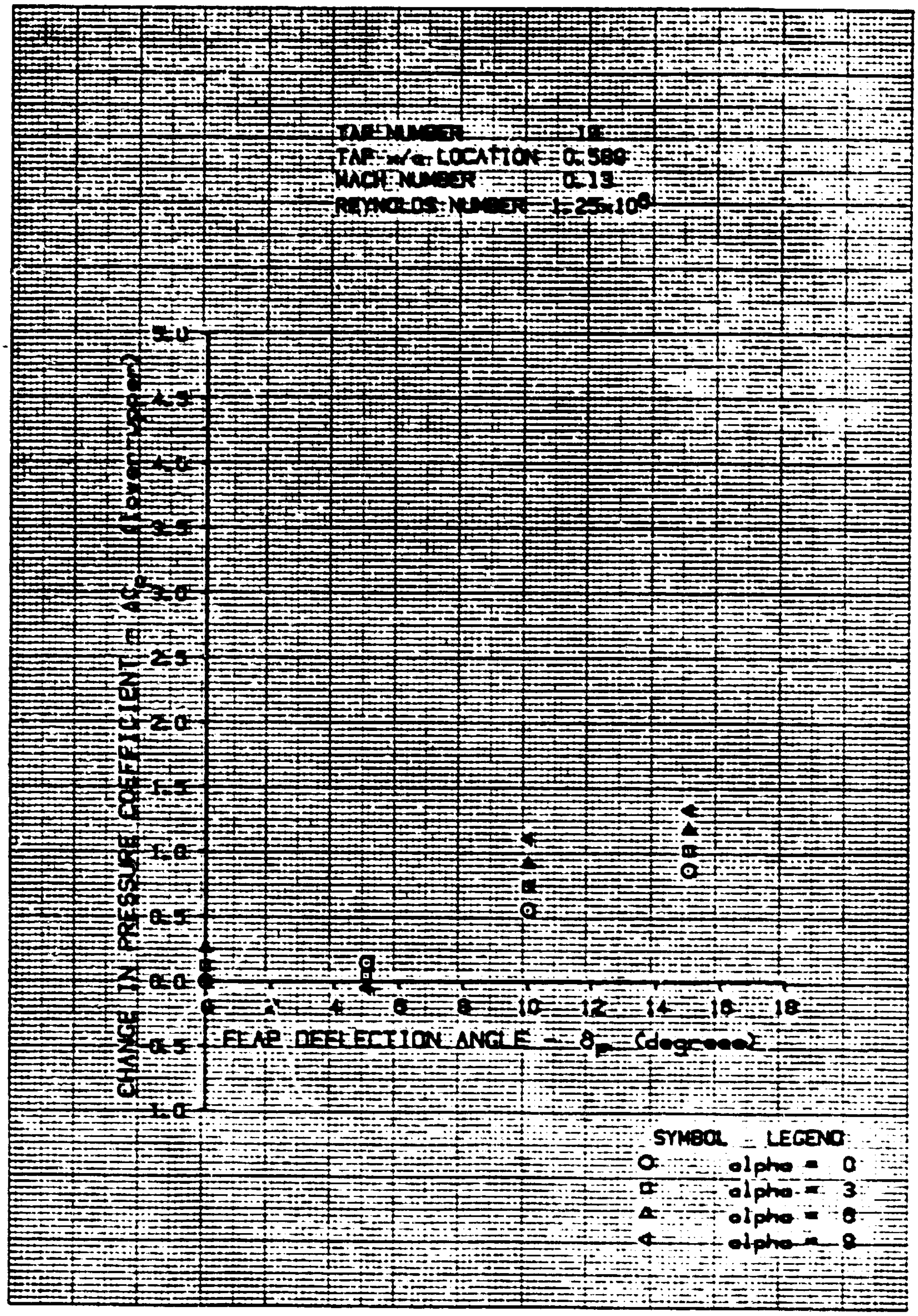
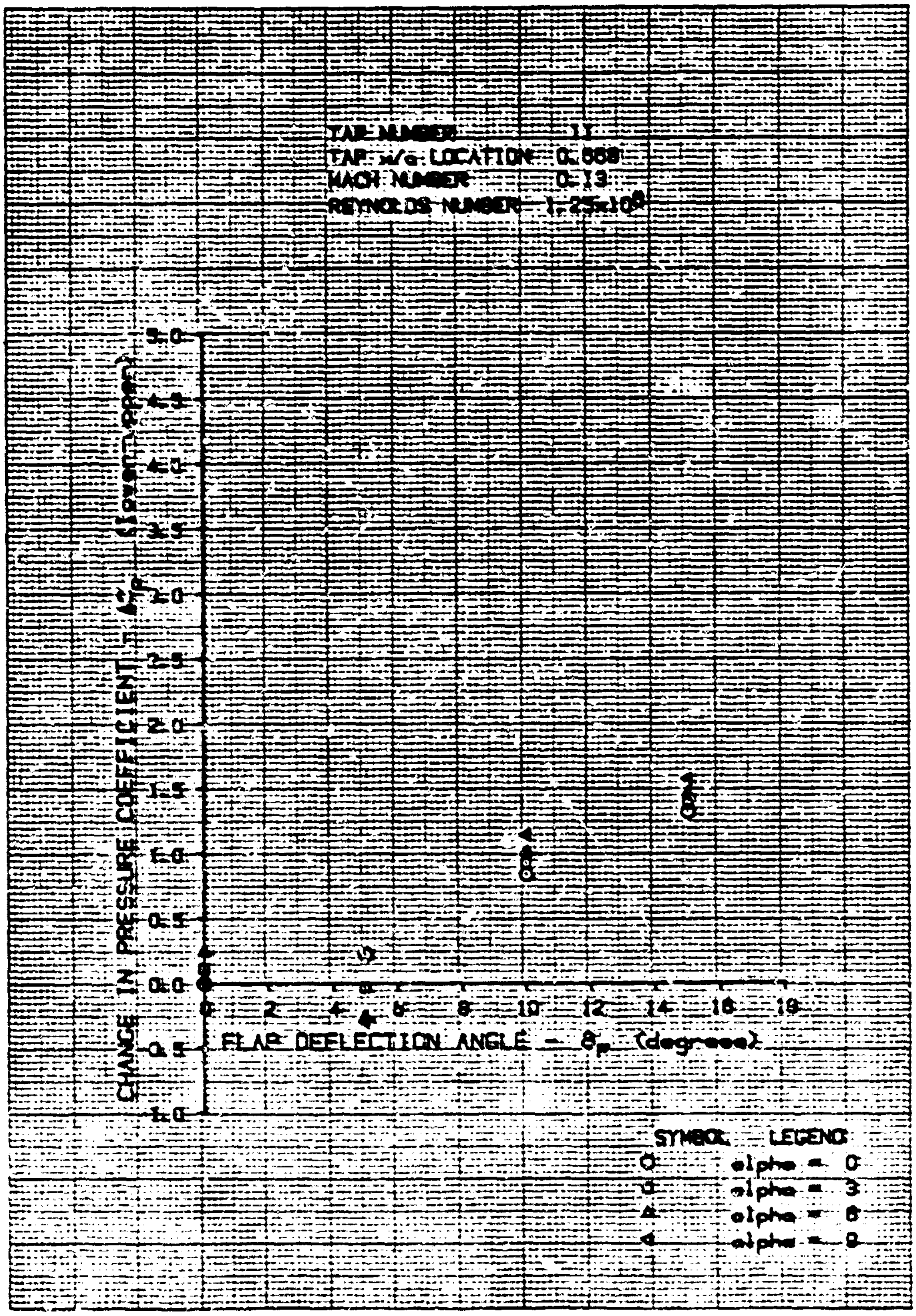
NOTE: THEORETICAL DATA INTERPOLATED TO SPECIFIC TAP LOCATIONS



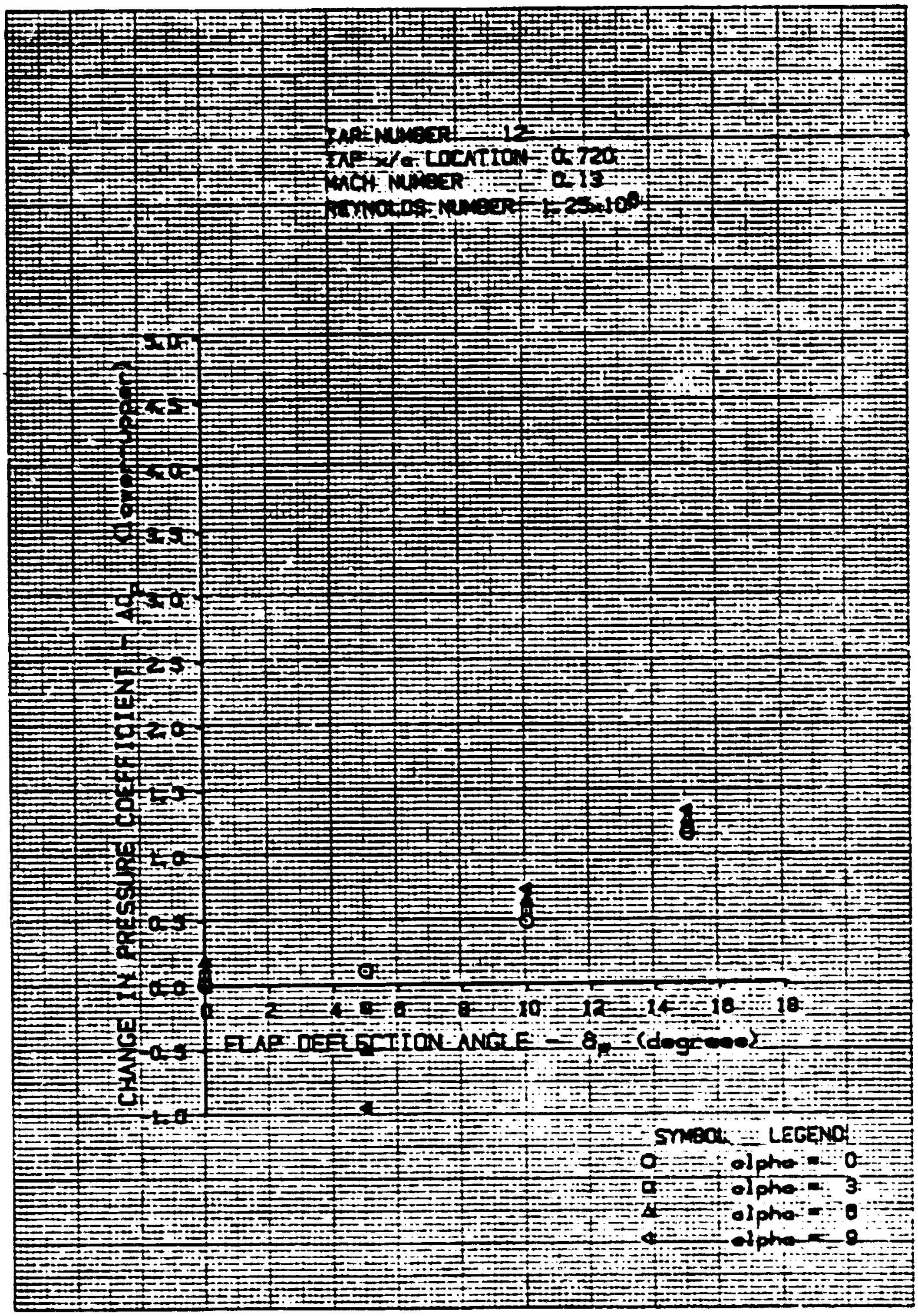
CALC	P. FINN	8-81	REVISED	DATE	FIGURE C.10 SEAP THEORETICAL CHANGE IN PRESSURE COEFFICIENTS - FLAP DEFLECTION SENSITIVITY	DATE 5-8-81
CHECK	R. HRABAK	8-81				
APPD						
APPD					UNIVERSITY OF KANSAS	PAGE 155

NOTE: THEORETICAL DATA INTERPOLATED TO SPECIFIC TAP LOCATIONS



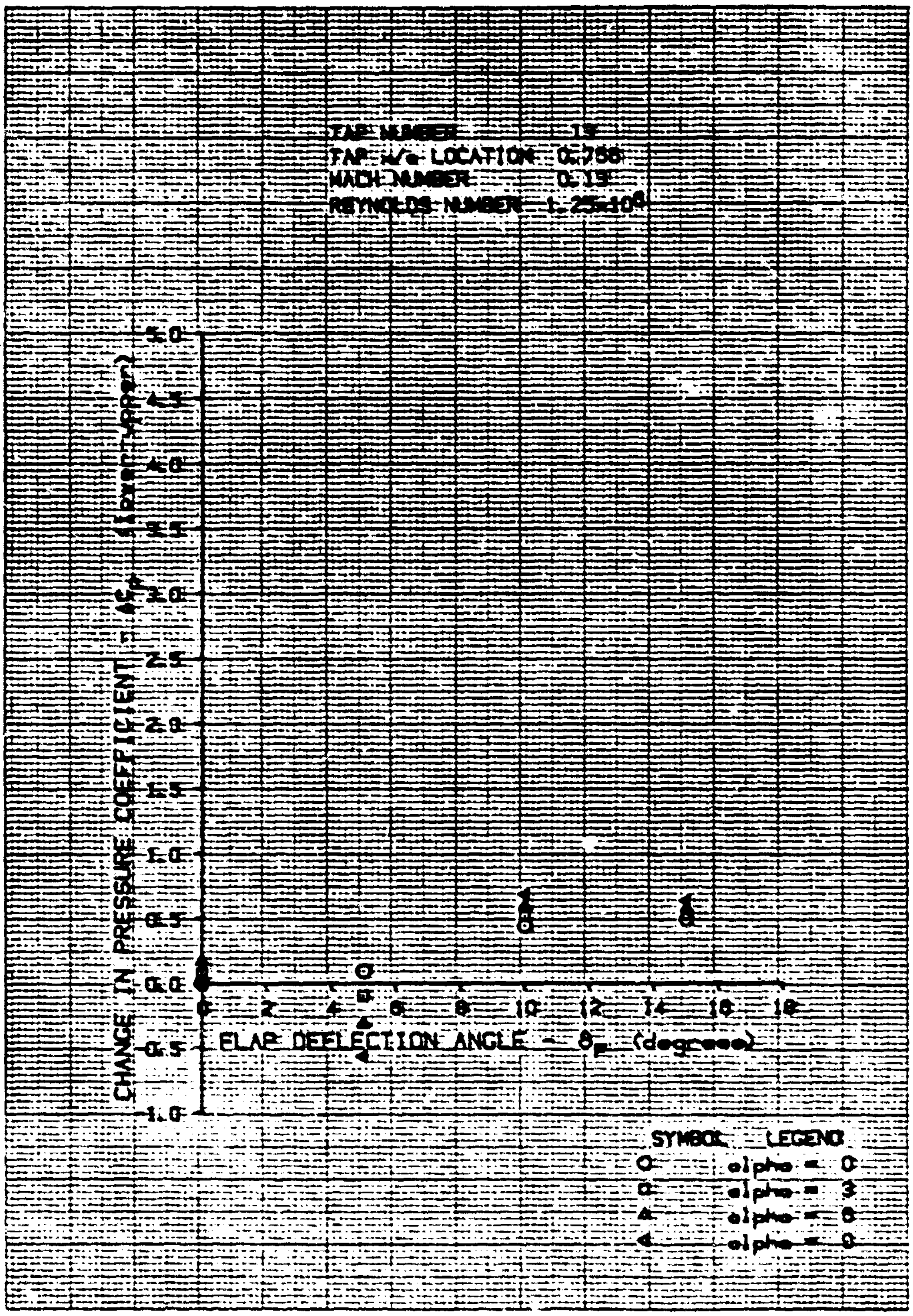
CALC	P. FINN	8-81	REVISED	DATE	FIGURE C.11 SEAP THEORETICAL CHANGE IN PRESSURE COEFFICIENTS - FLAP DEFLECTION SENSITIVITY	DATE 5-8-81
CHECK	R. WRABAK	8-81				
APPD						
APPD					UNIVERSITY OF KANSAS	PAGE 156

NOTE: THEORETICAL DATA INTERPOLATED TO SPECIFIC TAP LOCATIONS



CALC	P. FINN	8-81	REVISED	DATE	FIGURE C.12 SEAP THEORETICAL CHANGE IN PRESSURE COEFFICIENTS - FLAP DEFLECTION SENSITIVITY	DATE 7-8-81
CHECK	R. HRABAK	8-81				
APPD						
APPD					UNIVERSITY OF KANSAS	PAGE 157

NOTE: THEORETICAL DATA INTERPOLATED TO SPECIFIC TAP LOCATIONS



CALC	P. FINN	8-81	REVISED	DATE	FIGURE C.13 SEAP THEORETICAL CHANGE IN PRESSURE COEFFICIENTS - FLAP DEFLECTION SENSITIVITY	DATE 5-8-81
CHECK	R. HRABAK	8-81				
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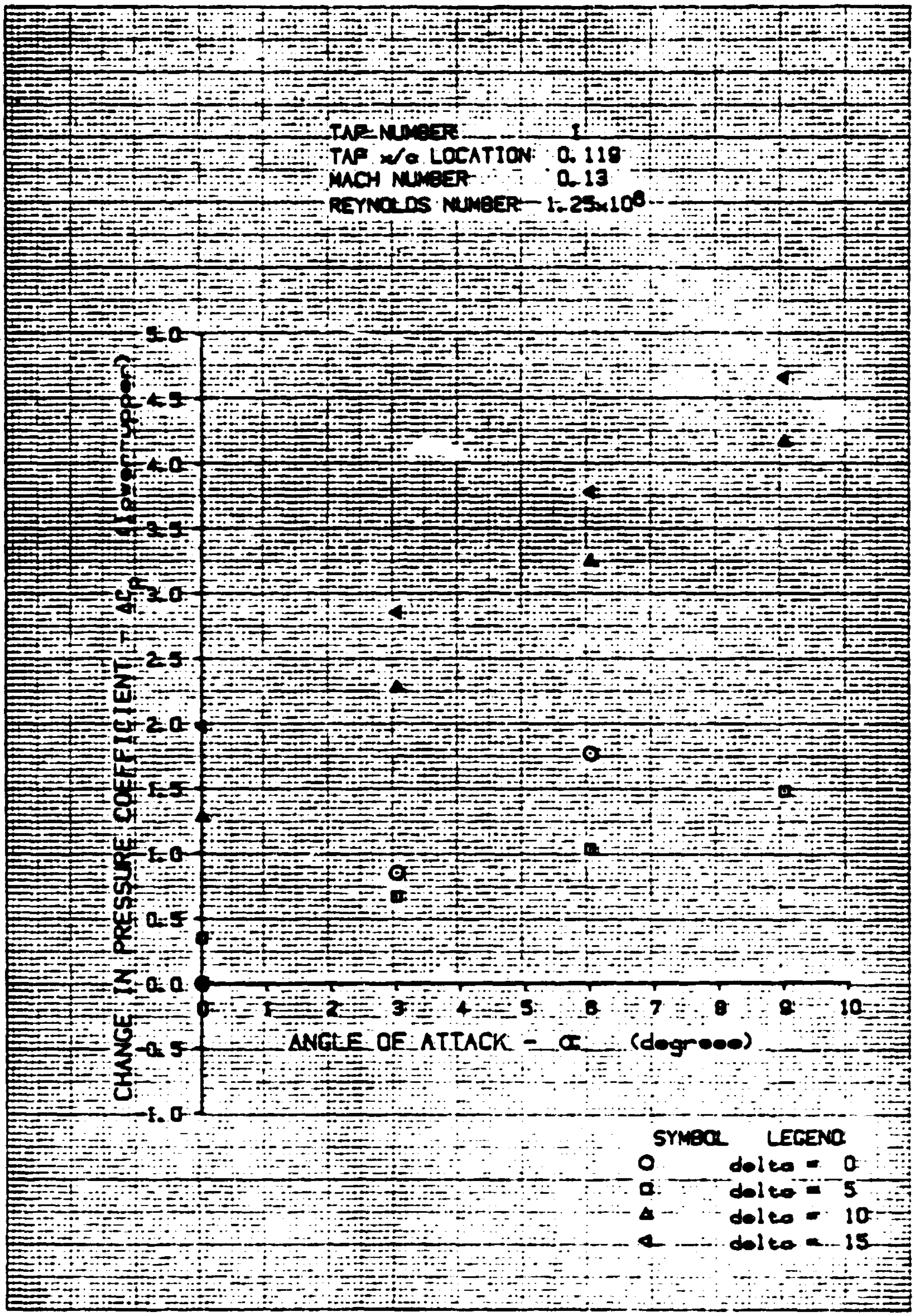
APPD					UNIVERSITY OF KANSAS	PAGE 158

C.6 GRAPHICAL OUTPUT--ANGLE OF ATTACK SENSITIVITY

NOTE: THEORETICAL DATA INTERPOLATED TO SPECIFIC TAP LOCATIONS



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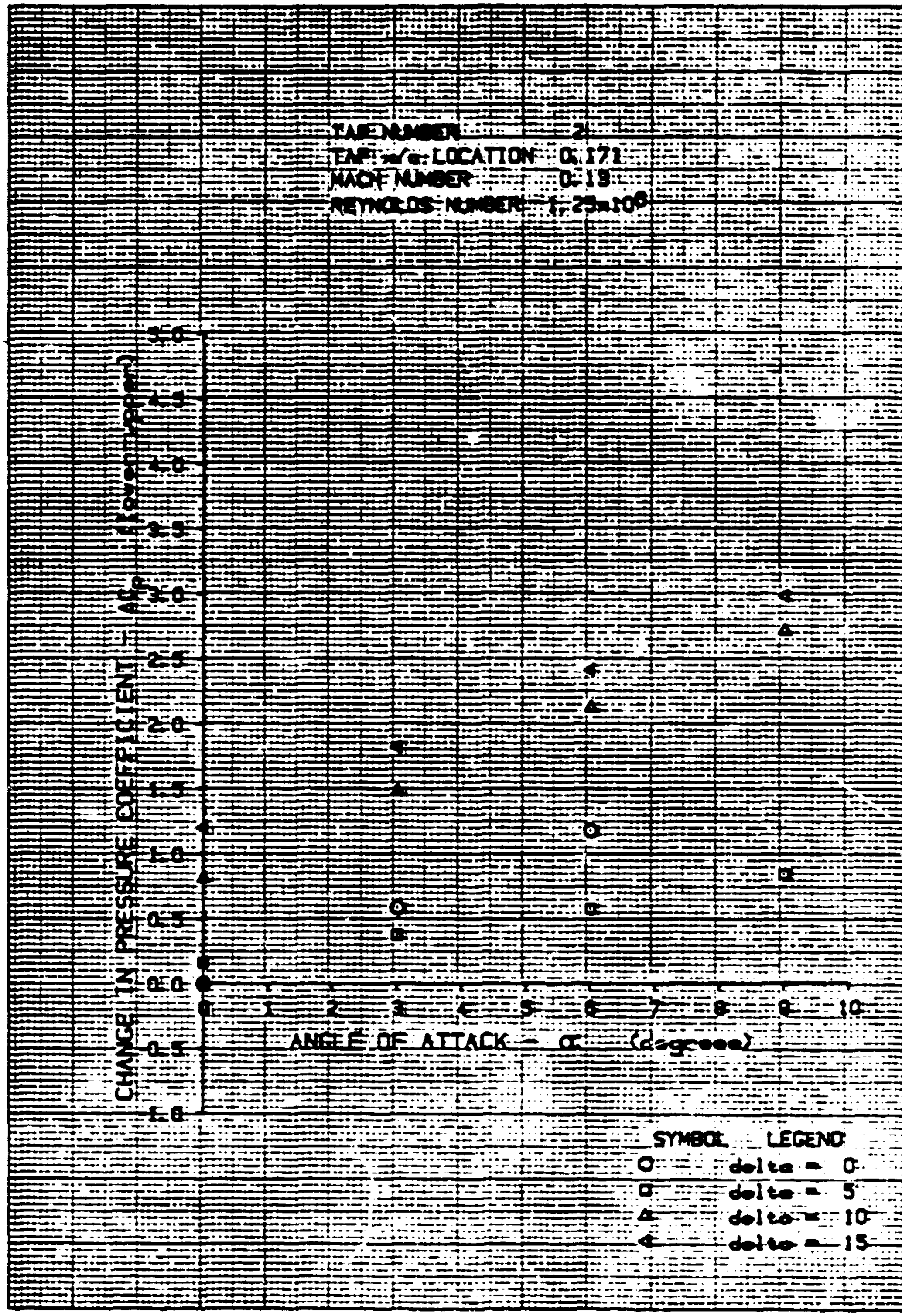
OF POOR QUALITY

CALC	P. FINN	8-81	REVISED	DATE	FIGURE C.14 SEAP THEORETICAL CHANGE IN PRESSURE COEFFICIENTS - ANGLE OF ATTACK SENSITIVITY
CHECK	R. HRABAK	8-81			
APPD					
APPD					UNIVERSITY OF KANSAS

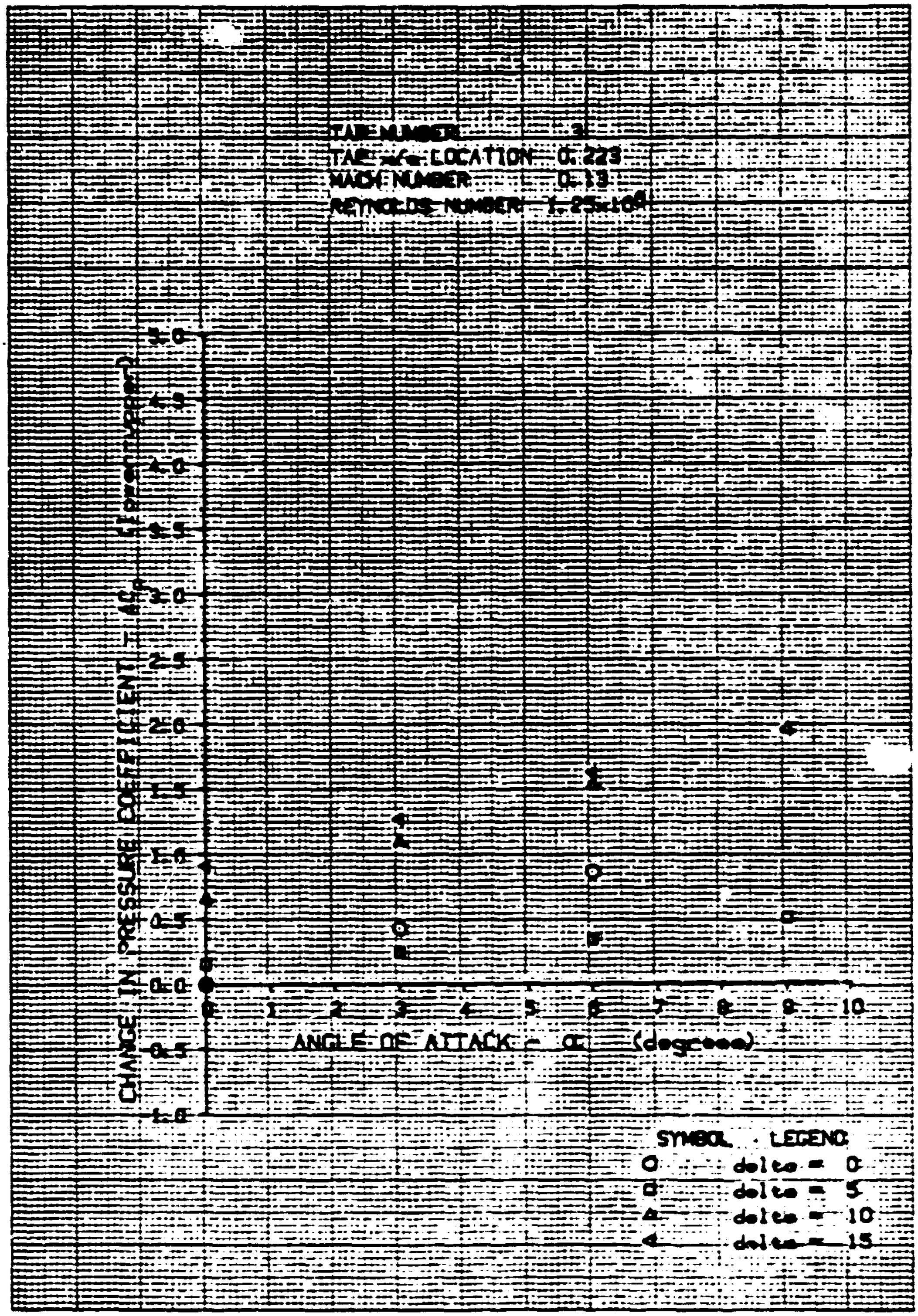
DATE 5-8-81

NOTE: THEORETICAL DATA INTERPOLATED TO SPECIFIC TAP LOCATIONS



CALC	P. FINN	8-81	REVISED	DATE	FIGURE C.13 SEAP THEORETICAL CHANGE IN PRESSURE COEFFICIENTS - ANGLE OF ATTACK SENSITIVITY	DATE 5-8-81
CHECK	R. WRABAK	8-81				
APPD						
APPD					UNIVERSITY OF KANSAS	PAGE 161

NOTE: THEORETICAL DATA INTERPOLATED TO SPECIFIC TAP LOCATIONS



CALC	P. FINN	8-81	REVISED	DATE	FIGURE C.16 SEAP THEORETICAL CHANGE IN PRESSURE COEFFICIENTS - ANGLE OF ATTACK SENSITIVITY	DATE 5-8-81
CHECK	R. HRABAK	8-81				
APPD						
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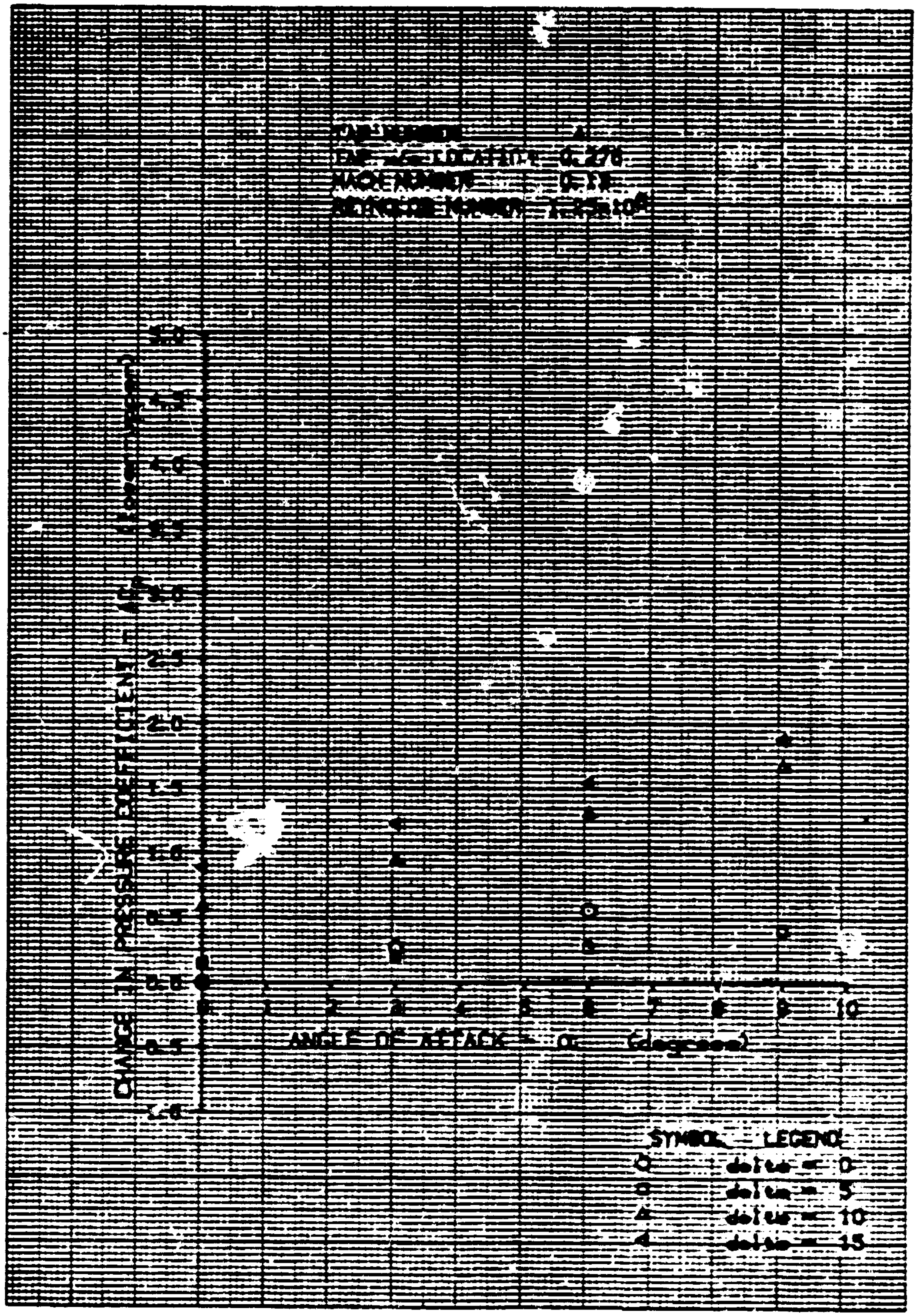
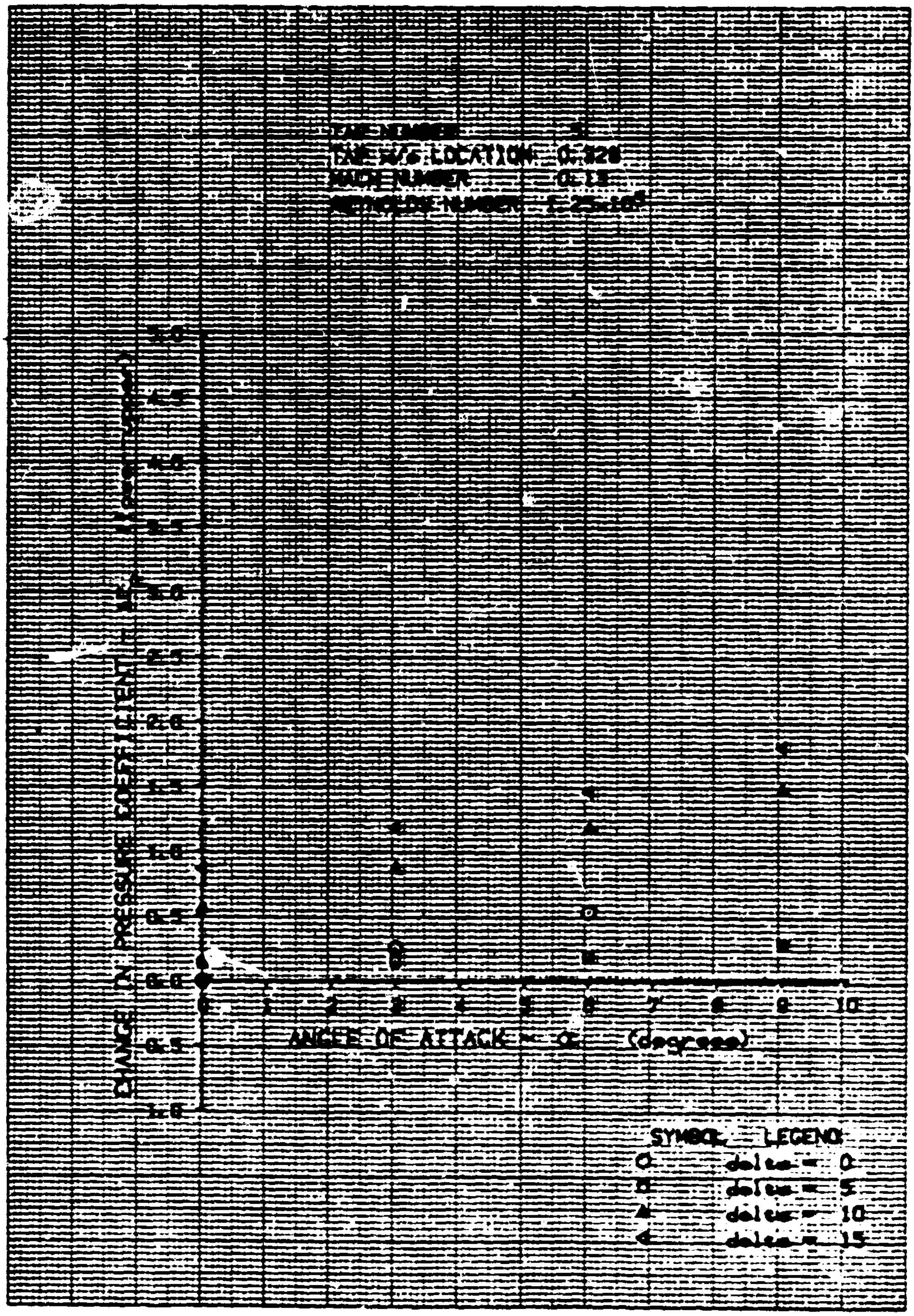
NOTE: THEORETICAL DATA INTERPOLATED TO SPECIFIC TAP LOCATIONS



CALC	P. FINN	8-81	REVISED	DATE	FIGURE C.17 SEAP THEORETICAL CHANGE IN PRESSURE COEFFICIENTS - ANGLE OF ATTACK SENSITIVITY
CHECK	R. HAABAK	8.81			DATE 5-8-81
APPD					
APPD					UNIVERSITY OF KANSAS
					PAGE 163

NOTE: THEORETICAL DATA INTERPOLATED TO SPECIFIC TAP LOCATIONS



CALC	P. FINN	8-81	REVISED	DATE	FIGURE C.18 SEAP THEORETICAL CHANGE IN PRESSURE COEFFICIENTS - ANGLE OF ATTACK SENSITIVITY	DATE 5-8-81
CHECK	R. HRABAK	8-81				
APPD						
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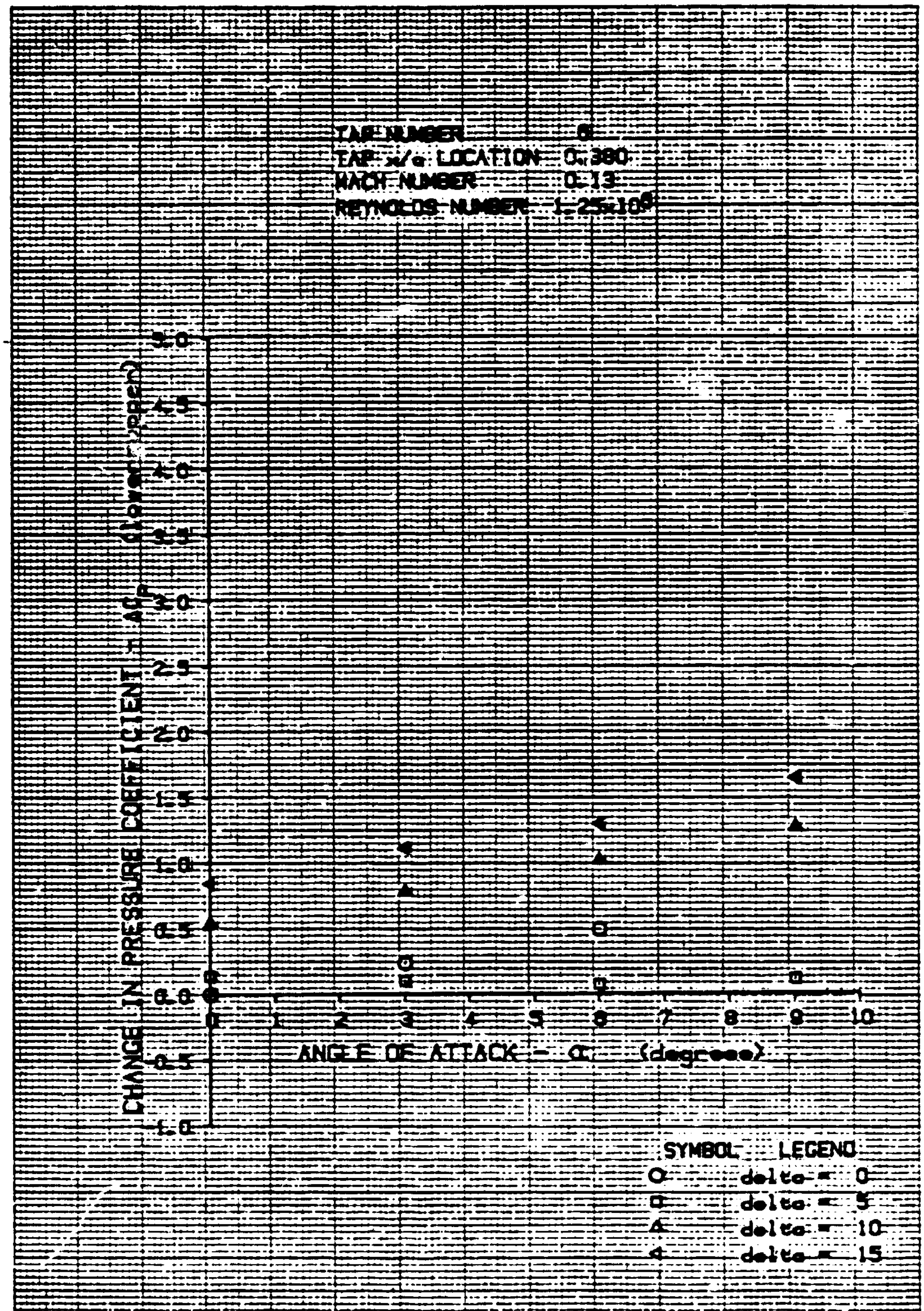
NOTE: THEORETICAL DATA INTERPOLATED TO SPECIFIC TAP LOCATIONS



CALC	P. FINN	8-81	REVISED	DATE	FIGURE C.19 SEAP THEORETICAL CHANGE IN PRESSURE COEFFICIENTS - ANGLE OF ATTACK SENSITIVITY	DATE 5-8-81
CHECK	R. URABAK	8-81				
APD						
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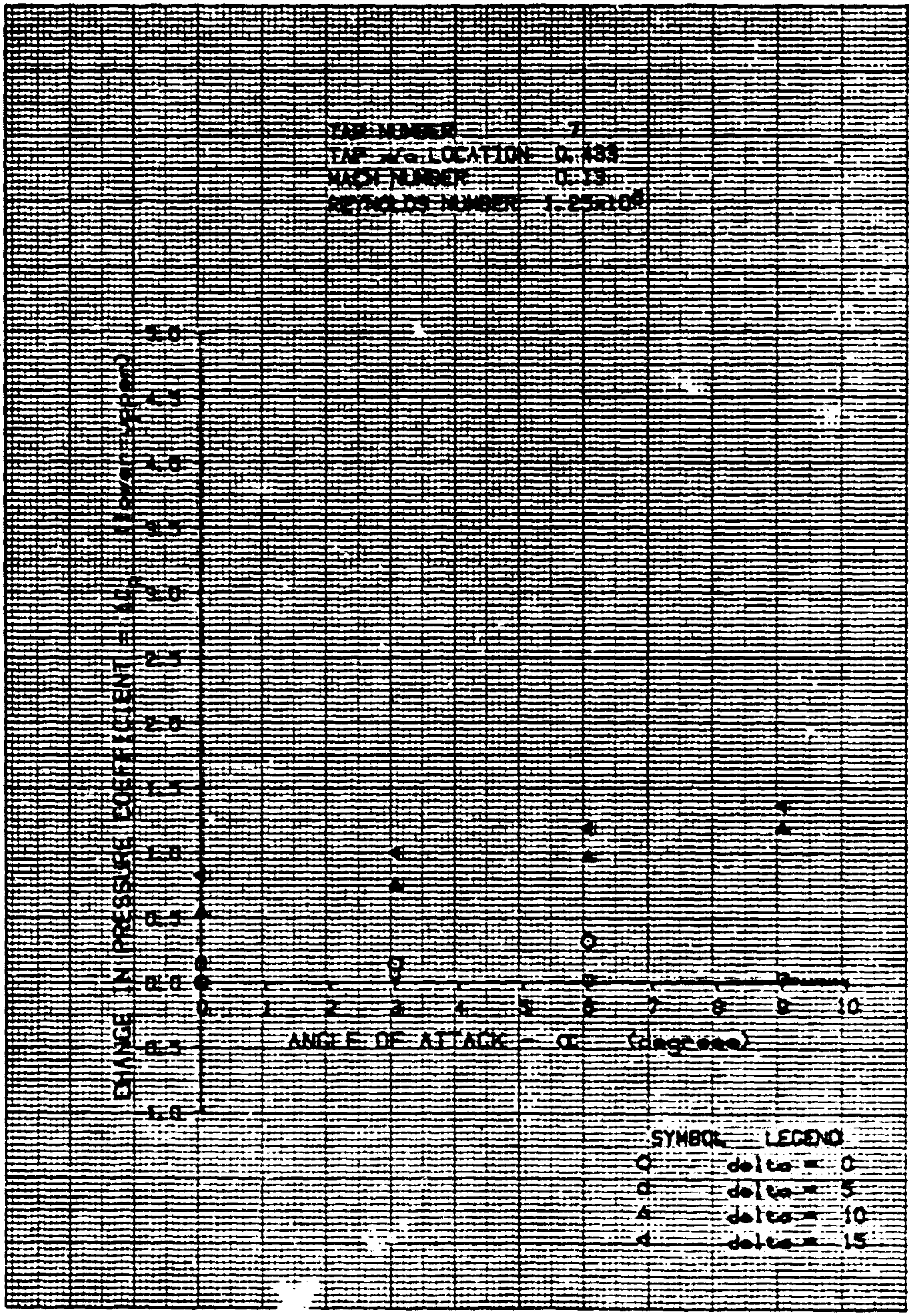
NOTE: THEORETICAL DATA INTERPOLATED TO SPECIFIC TAP LOCATIONS



CALC	P. FINN	8-81	REVISED	DATE	FIGURE C.20 SEAP THEORETICAL CHANGE IN PRESSURE COEFFICIENTS - ANGLE OF ATTACK SENSITIVITY	DATE 5-8-81
CHECK	R. HRABAK	8-81				
APPD						
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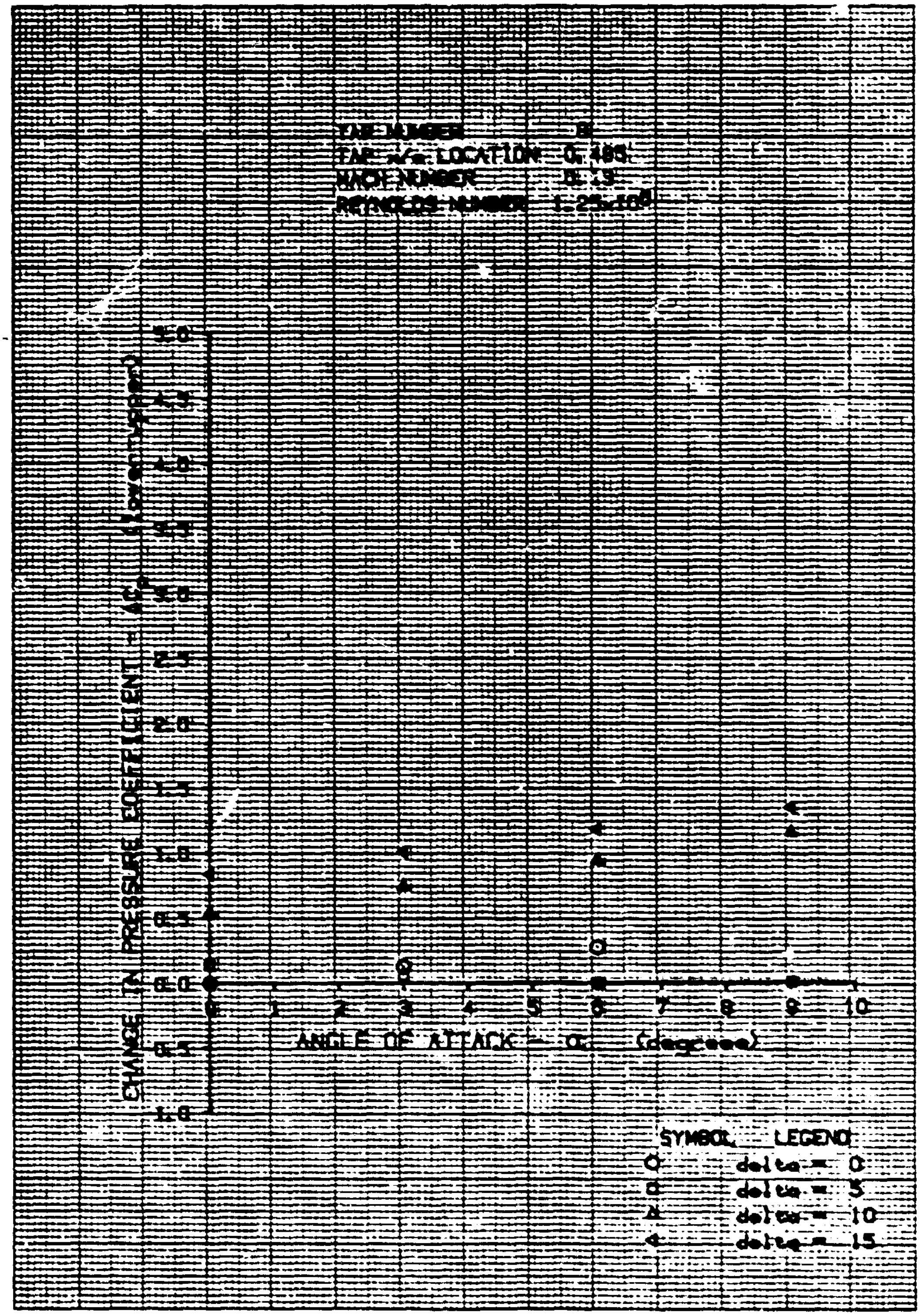
NOTE: THEORETICAL DATA INTERPOLATED TO SPECIFIC TAP LOCATIONS



CALC	P. FINN	8-81	REVISED	DATE	FIGURE C.21 SEAP THEORETICAL CHANGE IN PRESSURE COEFFICIENTS - ANGLE OF ATTACK SENSITIVITY	DATE 5-8-81
CHECK	R.HAABAK	8-81				
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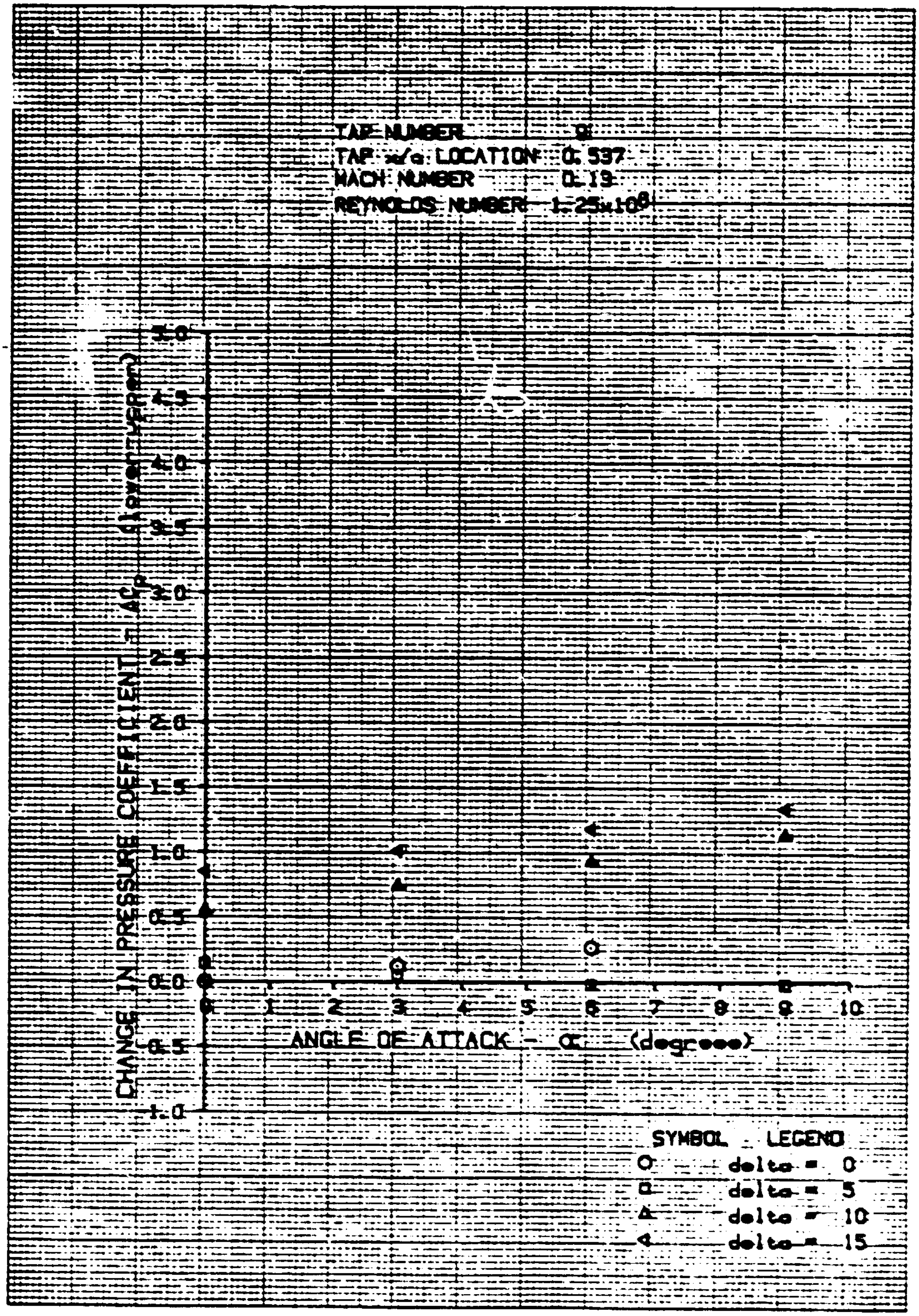
NOTE: THEORETICAL DATA INTERPOLATED TO SPECIFIC TAP LOCATIONS



CALC	P. FINN	8-81	REVISED	DATE	FIGURE C.22 SEAP THEORETICAL CHANGE IN PRESSURE COEFFICIENTS - ANGLE OF ATTACK SENSITIVITY	DATE 5-8-81
CHECK	R. HRABAK	8-81				
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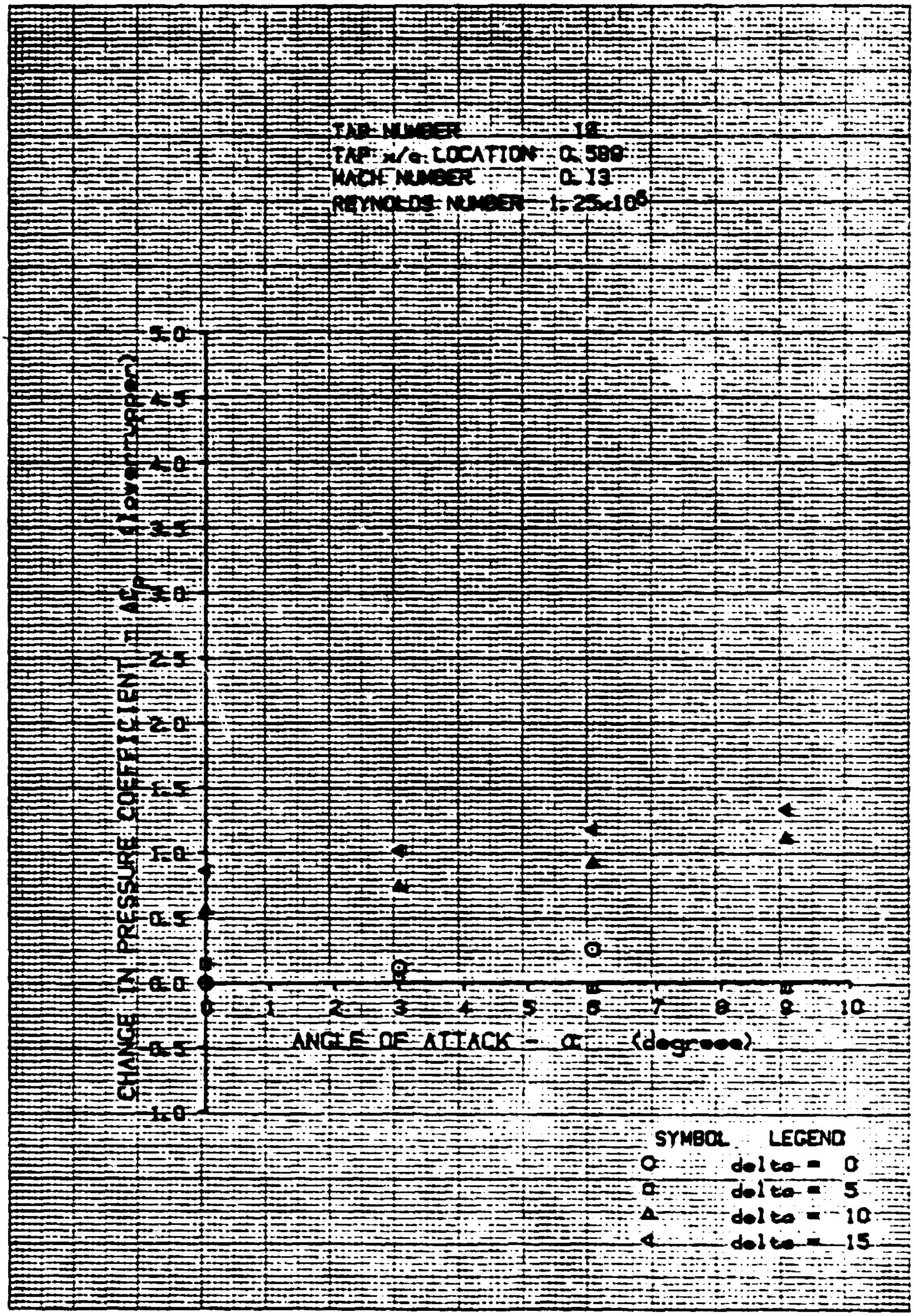
NOTE: THEORETICAL DATA INTERPOLATED TO : ECIFIC TAP LOCATIONS



CALC	P. FINN	8-81	REVISED	DATE	FIGURE C.23 SEAP THEORETICAL CHANGE IN PRESSURE COEFFICIENTS - ANGLE OF ATTACK SENSITIVITY	DATE 5-8-81
CHECK	R. HAABAK	8-81				
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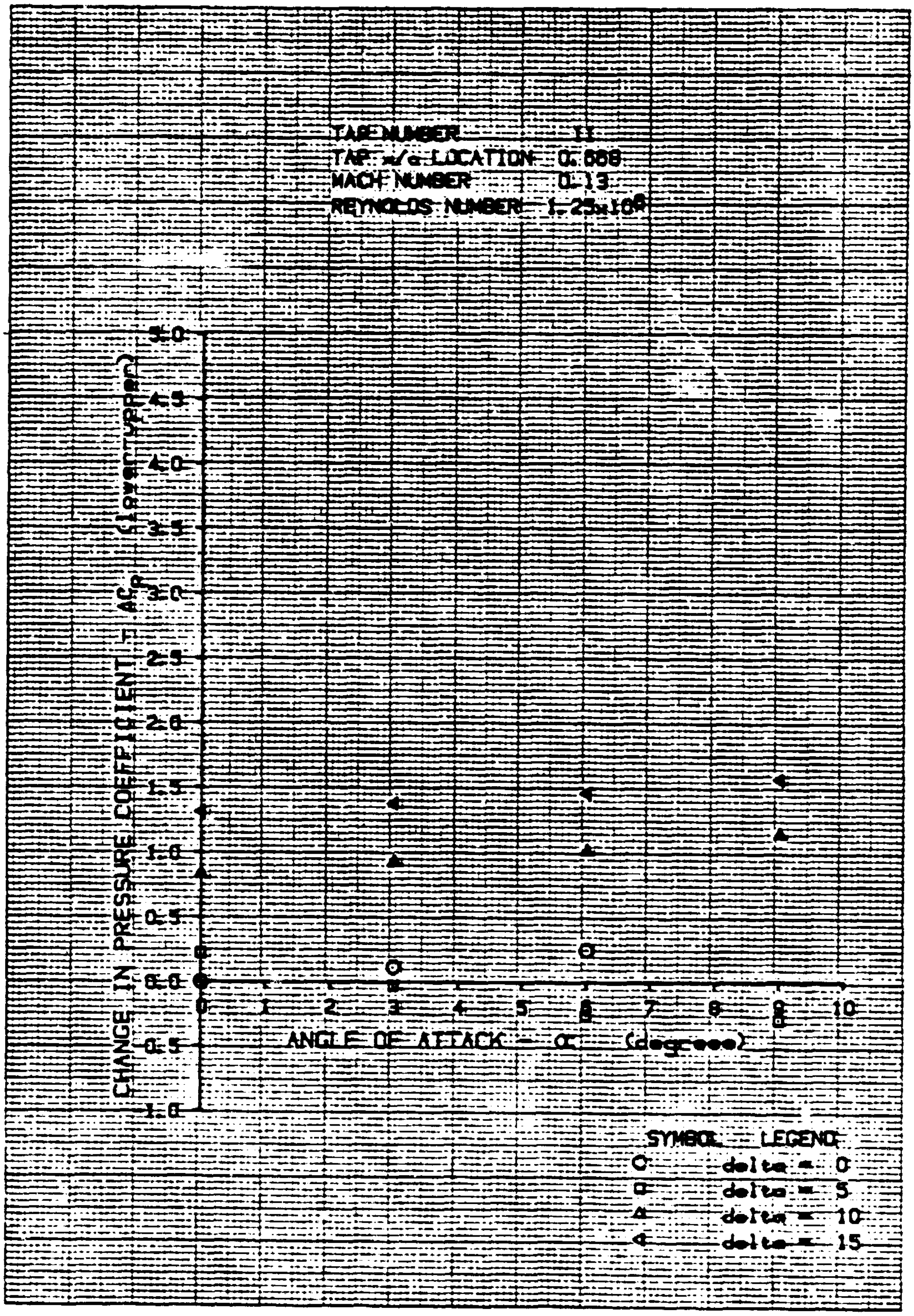
APPD					UNIVERSITY OF KANSAS	PAGE 169

NOTE: THEORETICAL DATA INTERPOLATED TO SPECIFIC TAP LOCATIONS



CALC	P. FINN	8-81	REVISED	DATE	FIGURE C.24 SEAP THEORETICAL CHANGE IN PRESSURE COEFFICIENTS - ANGLE OF ATTACK SENSITIVITY
CHECK	R. HRABAK	8-81			DATE 5-8-81
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APPD					UNIVERSITY OF KANSAS
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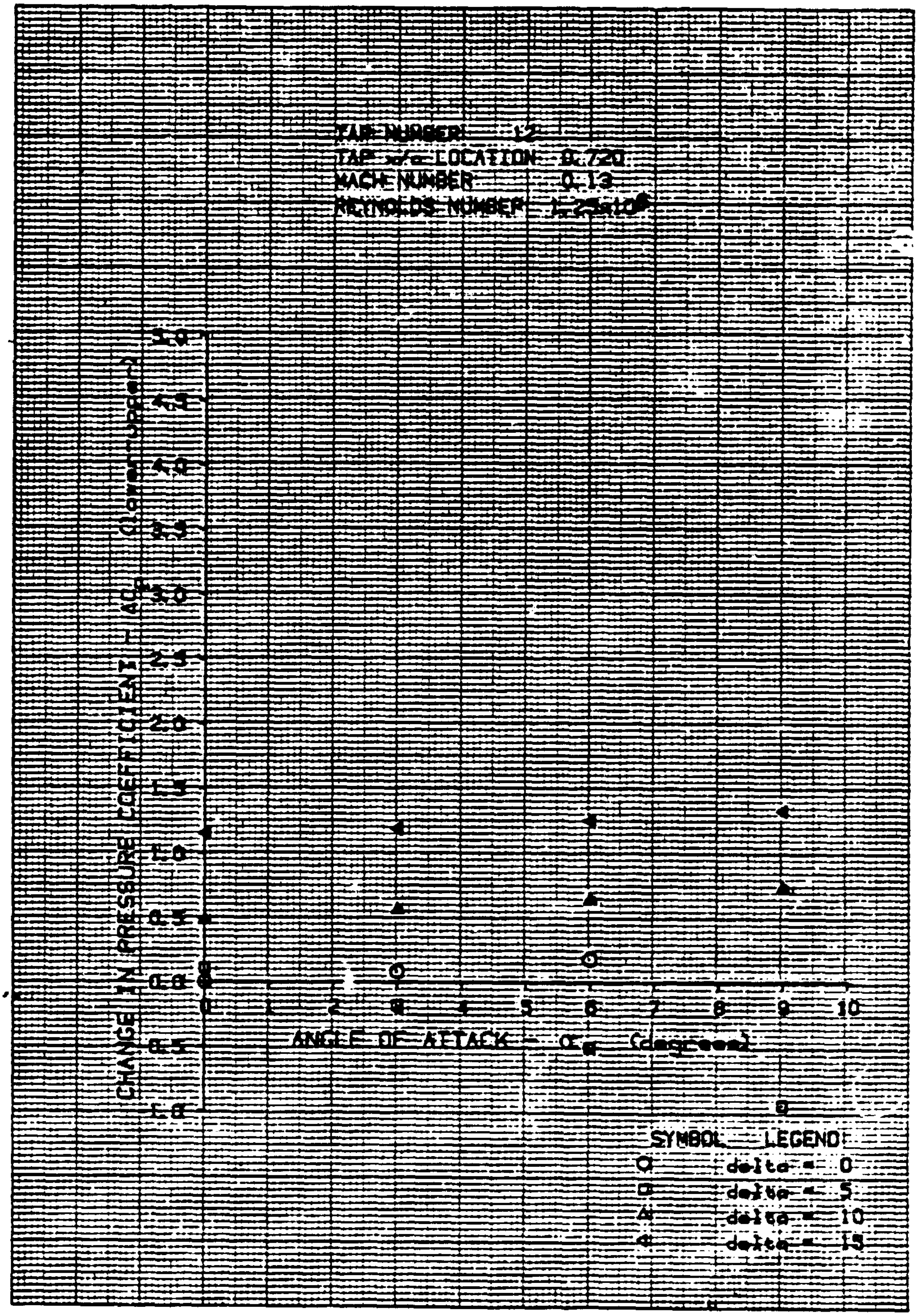
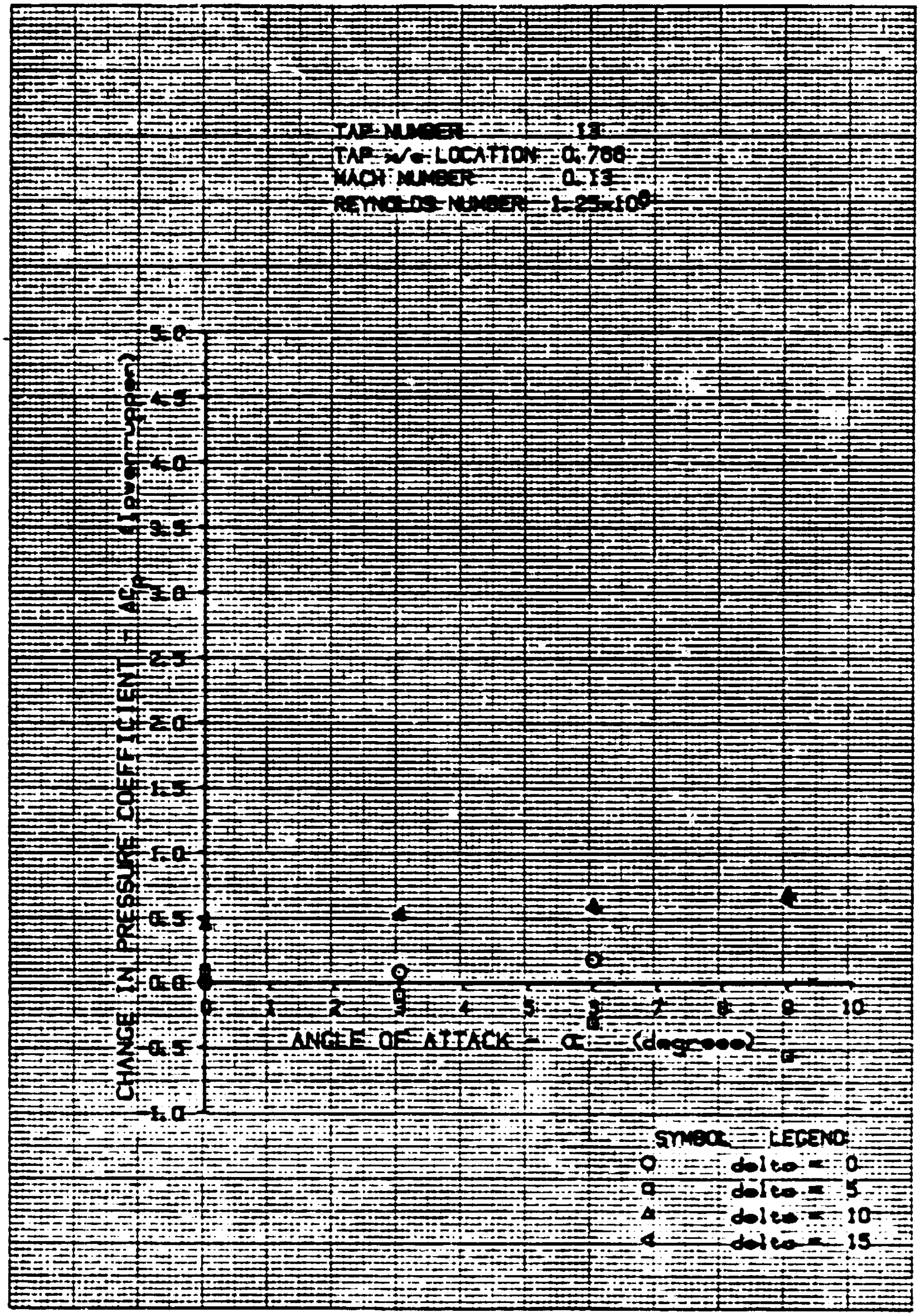
NOTE: THEORETICAL DATA INTERPOLATED TO SPECIFIC TAP LOCATIONS



			REVISED	DATE		
CALC	P. FINN	8-81			FIGURE C.25 SEAP THEORETICAL CHANGE IN PRESSURE COEFFICIENTS - ANGLE OF ATTACK SENSITIVITY	DATE 7-8-81
CHECK	R. HRABAK	8-81				
APPD						
APPD					UNIVERSITY OF KANSAS	PAGE 171

NOTE: THEORETICAL DATA INTERPOLATED TO SPECIFIC TAP LOCATIONS



CALC	P. FINN	8-81	REVISED	DATE	FIGURE C.28 SEAP THEORETICAL CHANGE IN PRESSURE COEFFICIENTS - ANGLE OF ATTACK SENSITIVITY	DATE 5-8-81
CHECK	R HAAGAK	8-81				
APPD						
APPD					UNIVERSITY OF KANSAS	PAGE 172

C.7 NUMERICAL REGRESSION DATA

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DELTA P PROJECT
SEAP

RESULTS OF LINEAR CURVE FITTING

FILE NUMBER 66 TAP NUMBER 1

DELTA (flap deflection angle) versus CHANGE IN PRESSURE COEFFICIENT AT DIFFERENT ANGLES ANGLES OF ATTACK (alpha)

alpha	SLOPE	INTERCEPT	COEFFICIENT OF DETERMINATION
0	0.137	-0.127	0.97
3	0.152	0.523	0.84
6	0.165	1.218	0.70
9	0.318	0.247	0.86

ALPHA (angle of attack) VERSES CHANGE IN PRESSURE COEFFICIENT AT DIFFERENT FLAP DEFLECTION ANGLES (delta)

delta	SLOPE	INTERCEPT	COEFFICIENT OF DETERMINATION
0	0.294	-0.009	1.00
5	0.124	0.324	0.99
10	0.319	1.301	1.00
15	0.298	1.974	1.00

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RESULTS OF LINEAR CURVE FITTING

FILE NUMBER 67 TAP NUMBER 2

DELTA (flap deflection angle) versus CHANGE IN PRESSURE COEFFICIENT AT DIFFERENT ANGLES ANGLES OF ATTACK (alpha)

alpha	SLOPE	INTERCEPT	COEFFICIENT OF DETERMINATION
0	0.085	-0.094	0.96
3	0.096	0.346	0.80
6	0.105	0.784	0.64
9	0.214	0.031	0.84

ALPHA (angle of attack) VERSES CHANGE IN PRESSURE COEFFICIENT AT DIFFERENT FLAP DEFLECTION ANGLES (delta)

delta	SLOPE	INTERCEPT	COEFFICIENT OF DETERMINATION
0	0.196	-0.000	1.00
5	0.074	0.155	1.00
10	0.211	0.830	1.00
15	0.197	1.215	1.00

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RESULTS OF LINEAR CURVE FITTING

FILE NUMBER 68   TAP NUMBER 3

DELTA (flap deflection angle) versus CHANGE IN PRESSURE COEFFICIENT AT DIFFERENT ANGLES ANGLES OF ATTACK (alpha)

alpha	SLOPE	INTERCEPT	COEFFICIENT OF DETERMINATION
0	0.065	-0.054	0.96
3	0.067	0.256	0.76
6	0.069	0.572	0.55
9	0.145	0.018	0.75

ALPHA (angle of attack) VERSES CHANGE IN PRESSURE COEFFICIENT AT DIFFERENT FLAP DEFLECTION ANGLES (delta)

delta	SLOPE	INTERCEPT	COEFFICIENT OF DETERMINATION
0	0.144	-0.001	1.00
5	0.038	0.141	0.98
10	0.144	0.662	1.00
15	0.116	0.918	1.00

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RESULTS OF LINEAR CURVE FITTING

FILE NUMBER 69   TAP NUMBER 4

DELTA (flap deflection angle) versus CHANGE IN PRESSURE COEFFICIENT AT DIFFERENT ANGLES ANGLES OF ATTACK (alpha)

alpha	SLOPE	INTERCEPT	COEFFICIENT OF DETERMINATION
0	0.062	-0.061	0.97
3	0.072	0.122	0.85
6	0.079	0.325	0.73
9	0.147	-0.159	0.86

ALPHA (angle of attack) VERSES CHANGE IN PRESSURE COEFFICIENT AT DIFFERENT FLAP DEFLECTION ANGLES (delta)

delta	SLOPE	INTERCEPT	COEFFICIENT OF DETERMINATION
0	0.094	-0.003	1.00
5	0.028	0.131	0.96
10	0.120	0.587	1.00
15	0.109	0.893	1.00

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DELTA P PROJECT
SEAP

RESULTS OF LINEAR CURVE FITTING

FILE NUMBER 70   TAP NUMBER 5

DELTA (flap deflection angle) versus CHANGE IN PRESSURE COEFFICIENT AT DIFFERENT ANGLES ANGLES OF ATTACK (alpha)

alpha	SLOPE	INTERCEPT	COEFFICIENT OF DETERMINATION
0	0.061	-0.061	0.97
3	0.070	0.090	0.84
6	0.075	0.266	0.70
9	0.153	-0.356	0.90

ALPHA (angle of attack) VERSES CHANGE IN PRESSURE COEFFICIENT AT DIFFERENT FLAP DEFLECTION ANGLES (delta)

delta	SLOPE	INTERCEPT	COEFFICIENT OF DETERMINATION
0	0.088	-0.003	1.00
5	0.013	0.125	0.84
10	0.100	0.564	1.00
15	0.102	0.869	1.00

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FILE NUMBER 71 TAP NUMBER 6

DELTA (flap deflection angle) versus CHANGE IN PRESSURE COEFFICIENT AT DIFFERENT ANGLES ANGLES OF ATTACK (alpha)

alpha	SLOPE	INTERCEPT	COEFFICIENT OF DETERMINATION
0	0.059	-0.059	0.97
3	0.066	0.061	0.82
6	0.067	0.216	0.63
9	0.153	-0.525	0.92

ALPHA (angle of attack) VERSES CHANGE IN PRESSURE COEFFICIENT AT DIFFERENT FLAP DEFLECTION ANGLES (delta)

delta	SLOPE	INTERCEPT	COEFFICIENT OF DETERMINATION
0	0.082	-0.003	1.00
5	-0.004	0.122	0.31
10	0.080	0.544	1.00
15	0.085	0.840	0.99

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RESULTS OF LINEAR CURVE FITTING

FILE NUMBER 72 TAP NUMBER 7

DELTA (flap deflection angle) versus CHANGE IN PRESSURE COEFFICIENT AT DIFFERENT ANGLES ANGLES OF ATTACK (alpha)

alpha	SLOPE	INTERCEPT	COEFFICIENT OF DETERMINATION
0	0.058	-0.056	0.97
3	0.065	0.004	0.84
6	0.071	0.085	0.70
9	0.133	-0.478	0.85

ALPHA (angle of attack) VERSUS CHANGE IN PRESSURE COEFFICIENT AT DIFFERENT FLAP DEFLECTION ANGLES (delta)

delta	SLOPE	INTERCEPT	COEFFICIENT OF DETERMINATION
0	0.053	-0.004	1.00
5	-0.014	0.122	0.83
10	0.070	0.540	1.00
15	0.058	0.829	1.00

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RESULTS OF LINEAR CURVE FITTING

FILE NUMBER 73 TAP NUMBER 8

DELTA (flap deflection angle) versus CHANGE IN PRESSURE COEFFICIENT AT DIFFERENT ANGLES ANGLES OF ATTACK (alpha)

alpha	SLOPE	INTERCEPT	COEFFICIENT OF DETERMINATION
0	0.059	-0.057	0.97
3	0.066	-0.013	0.85
6	0.073	0.047	0.73
9	0.134	-0.513	0.85

ALPHA (angle of attack) VERSES CHANGE IN PRESSURE COEFFICIENT AT DIFFERENT FLAP DEFLECTION ANGLES (delta)

delta	SLOPE	INTERCEPT	COEFFICIENT OF DETERMINATION
0	0.046	-0.003	1.00
5	-0.017	0.124	0.86
10	0.067	0.547	1.00
15	0.056	0.841	1.00

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RESULTS OF LINEAR CURVE FITTING

FILE NUMBER 74 TAP NUMBER 9

DELTA (flap deflection angle) versus CHANGE IN PRESSURE COEFFICIENT AT DIFFERENT ANGLES ANGLES OF ATTACK (alpha)

alpha	SLOPE	INTERCEPT	COEFFICIENT OF DETERMINATION
0	0.059	-0.057	0.97
3	0.067	-0.020	0.85
6	0.074	0.034	0.72
9	0.136	-0.548	0.86

ALPHA (angle of attack) VERSES CHANGE IN PRESSURE COEFFICIENT AT DIFFERENT FLAP DEFLECTION ANGLES (delta)

delta	SLOPE	INTERCEPT	COEFFICIENT OF DETERMINATION
0	0.044	-0.003	1.00
5	-0.020	0.125	0.89
10	0.064	0.553	1.00
15	0.054	0.853	1.00

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FILE NUMBER 75 TAP NUMBER 10

DELTA (flap deflection angle) versus CHANGE IN PRESSURE COEFFICIENT AT DIFFERENT ANGLES ANGLES OF ATTACK (alpha)

alpha	SLOPE	INTERCEPT	COEFFICIENT OF DETERMINATION
0	0.060	-0.058	0.97
3	0.068	-0.027	0.85
6	0.074	0.020	0.72
9	0.138	-0.583	0.87

ALPHA (angle of attack) VERSES CHANGE IN PRESSURE COEFFICIENT AT DIFFERENT FLAP DEFLECTION ANGLES (delta)

delta	SLOPE	INTERCEPT	COEFFICIENT OF DETERMINATION
0	0.043	-0.003	1.00
5	-0.023	0.127	0.91
10	0.060	0.559	1.00
15	0.051	0.865	1.00

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RESULTS OF LINEAR CURVE FITTING

FILE NUMBER 76 TAP NUMBER 11

DELTA (flap deflection angle) versus CHANGE IN PRESSURE COEFFICIENT AT DIFFERENT ANGLES ANGLES OF ATTACK (alpha)

alpha	SLOPE	INTERCEPT	COEFFICIENT OF DETERMINATION
0	0.091	-0.089	0.97
3	0.095	-0.115	0.84
6	0.098	-0.123	0.68
9	0.186	-1.060	0.91

ALPHA (angle of attack) VERSES CHANGE IN PRESSURE COEFFICIENT AT DIFFERENT FLAP DEFLECTION ANGLES (delta)

delta	SLOPE	INTERCEPT	COEFFICIENT OF DETERMINATION
0	0.041	-0.003	1.00
5	-0.060	0.180	0.92
10	0.033	0.831	0.99
15	0.027	1.306	0.98

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RESULTS OF LINEAR CURVE FITTING

FILE NUMBER 77 TAP NUMBER 12

DELTA (flap deflection angle) versus CHANGE IN PRESSURE COEFFICIENT AT DIFFERENT ANGLES ANGLES OF ATTACK (alpha)

alpha	SLOPE	INTERCEPT	COEFFICIENT OF DETERMINATION
0	0.076	-0.139	0.90
3	0.081	-0.193	0.76
6	0.087	-0.264	0.57
9	0.228	-1.911	0.93

ALPHA (angle of attack) VERSES CHANGE IN PRESSURE COEFFICIENT AT DIFFERENT FLAP DEFLECTION ANGLES (delta)

delta	SLOPE	INTERCEPT	COEFFICIENT OF DETERMINATION
0	0.030	-0.002	1.00
5	-0.117	0.143	0.99
10	0.027	0.480	1.00
15	0.019	1.135	0.97

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RESULTS OF LINEAR CURVE FITTING

FILE NUMBER 78 TAP NUMBER 13

DELTA (flap deflection angle) versus CHANGE IN PRESSURE COEFFICIENT AT DIFFERENT ANGLES ANGLES OF ATTACK (alpha)

alpha	SLOPE	INTERCEPT	COEFFICIENT OF DETERMINATION
0	0.036	-0.016	0.91
3	0.039	-0.035	0.64
6	0.042	-0.059	0.41
9	0.120	-0.949	0.72

ALPHA (angle of attack) VERSES CHANGE IN PRESSURE COEFFICIENT AT DIFFERENT FLAP DEFLECTION ANGLES (delta)

delta	SLOPE	INTERCEPT	COEFFICIENT OF DETERMINATION
0	0.029	-0.002	1.00
5	-0.073	0.109	1.00
10	0.027	0.439	1.00
15	0.015	0.485	0.99

APPENDIX D

THEORETICAL FREQUENCY ANALYSIS DATA

D.1 LOW DYNAMIC PRESSURE

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************************************************************
              DELTA P FREQUENCY ANALYSIS FC1
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INPUT DATA

Wing Area (D[80],ft↑2)	174.0000000
Weight (D[71],lb)	2645.0000000
Wing Span (D[72],ft)	35.8000000
MAC (D[73],ft)	4.9000000
Airspeed (D[74],ft/s)	90.9000000
Density (D[75],slugs/ft↑3)	0.0020500
Angle of attack (D[76],rad)	0.0000000
Theta initial (D[77],rad)	0.0000000
Iyyb (D[81],slugs-ft↑2)	1346.0000000
CL1 (D[95])	0.3100000
CD1 (D[96])	0.0310000
CXT1 (D[97])	0.0310000
CM1 (D[88])	0.0000000
CMT1 (D[89])	0.0000000

Nondimensional derivatives Dimensional derivatives

LONGITUDINAL DERIVATIVES

CDU (D[1])	0.0000	XU (1/s)	-0.0122
CXTU (D[2])	-0.0930	XTU (1/s)	-0.0061
CDA (D[3])	0.1300	XA (ft/s↑2)	3.2267
CDDE (D[4])	0.0600	XDE (ft/s↑2)	-1.0756
CLU (D[6])	0.0000	ZU (1/s)	-0.1223
CLA (D[7])	4.6000	ZA (ft/s↑2)	-83.0147
CLAD (D[8])	1.7000	ZAD (ft/s)	-0.8214
CLQ (D[9])	3.9000	ZQ (ft/s)	-1.8843
CLDE (D[10])	0.4300	ZDE (ft/s↑2)	-7.7081
CMU (D[12])	0.0000	MU (1/fts)	0.0000
CMTU (D[13])	0.0000	MTU (1/fts)	0.0000
[illegible] 4])	-0.8900	MA (1/s↑2)	-4.7747
[illegible] 5])	0.0000	MTA (1/s↑2)	0.0000
[illegible] 16])	-5.2000	MAD (1/s)	-0.7519
CMQ (D[17])	-12.4000	MQ (1/s)	-1.7930
CMDE (D[18])	-1.2800	MDE (1/s↑2)	-6.8669

****
DELTA P FREQUENCY ANALYSIS FC1
****

TRANSFER FUNCTION POLYNOMIAL COEFFICIENTS

THE COEFFICIENTS OF THE LONGITUDINAL CHARACTERISTIC EQUATION ARE:

```
A=        91.72136   B=      316.08207   C=      580.02367
D=        14.18981   E=       18.78257

          THE COEFFICIENTS OF THE NUMERATOR U(S) ARE:
           0.00000   AU=     -98.65111   BU=    -363.02499
CU=    17443.94743   DU=   17156.83612

         THE COEFFICIENTS OF THE NUMERATOR ALPHA(S) ARE:
           0.00000   AA=      -7.70812   BA=    -625.09400
CA=      -11.22826   DA=     -27.01314

        THE COEFFICIENTS OF THE NUMERATOR THETA(S) ARE:
           0.00000             0.00000   AT=    -624.04734
BT=     -544.79548   CT=     -13.11681
```

STANDARD FORMAT FOR LONGITUDINAL TRANSFER FUNCTIONS

U(S)/DELTA-E(S) COEFFICIENTS ARE:

KUDE	913.44451
TU1	1.03184
TU2	0.06748
TU3	-0.08258
OMN SP	2.50357
ZT SP	0.68689
OMN P	0.18075
ZT P	0.01869

ALPHA(S)/DELTA-E(S) COEFFICIENTS ARE:

KALPHADE	-1.43820
TALPHA1	0.01233
OMN ALPHA	0.20790
ZT ALPHA	0.04193
OMN SP	2.50357
ZT SP	0.68689
OMN P	0.18075
ZT P	0.01869

THETA(S)/DELTA-E(S) COEFFICIENTS ARE:

KTHETADE	-0.69835
TTHETA1	40.35522
TTHETA2	1.17893
OMN SP	2.50357
ZT SP	0.68689
OMN P	0.18075
ZT P	0.01869

D.1.1 WITH PRESSURE SENSOR (PRESSURE COMMAND)

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*****************************************************
                   DELTA P FREQUENCY ANALYSIS FC1
*****************************************************

N0(S) COEFFICIENTS
  1.000E 01  5.000E 01
D0(S) COEFFICIENTS
  1.000E 00  1.500E 01  7.000E 01
N1(S) COEFFICIENTS
  6.240E 02  5.448E 02  1.310E 01
D1(S) COEFFICIENTS
  9.170E 01  3.161E 02  5.860E 02  1.420E 01  1.[illegible]E 01
N2(S) COEFFICIENTS
  1.000E 00
D2(S) COEFFICIENTS
  1.000E 00


N[0]N[1]D[2]=

  6.240E 03  3.665E 04  2.737E 04  6.550E 02
N[0]N[1]N[2]=

  6.240E 03  3.665E 04  2.737E 04  6.550E 02
               Real    Imaginary                        Real    Imaginary
ROOT NO. 3    -0.025    0.000          ROOT NO. 2     -5.000     0.000
ROOT NO. 1    -0.348    0.000

K=      0.000
  D[0]D[1]D[2]+KN[0]N[1]N[2]=

  9.170E 01  1.692E 03  1.174E 04  3.084E 04  4.0[illegible]E 04  1.2[illegible]E [illegible]
  1.316E 03
               Real    Imaginary                        Real    Imaginary
ROOT NO. 6    -7.500   -3.709          ROOT NO. 5     -7.500    [illegible]
ROOT NO. 4    -1.720   -1.819          ROOT NO. 3     -0.003   -0.1[illegible]
ROOT NO. 2    -1.720    1.819          ROOT NO. 1     -0.003    0.1[illegible]

K=      0.200
  D[0]D[1]D[2]+KN[0]N[1]N[2]=

  9.170E 01  1.692E 03  1.174E 04  3.209E 04  4.816E 04  6.750E 0[illegible]
  1.447E 03
               Real    Imaginary                        Real    Imaginary
ROOT NO. 6    -7.495   -3.553          ROOT NO. 5     -7.495     3.553
ROOT NO. 4    -1.663   -2.043          ROOT NO. 3     -0.066    -0.170
ROOT NO. 2    -1.663    2.043          ROOT NO. 1     -0.066     0.170

K=      0.500
  D[0]D[1]D[2]+KN[0]N[1]N[2]=

  9.170E 01  1.692E 03  1.174E 04  3.396E 04  5.[illegible]E 04  1.496E 04
  1.644E 03
               Real    Imaginary                        Real    Imaginary
ROOT NO. 6    -7.497   -3.314          ROOT NO. 5     -7.497     3.314
ROOT NO. 4    -1.588   -2.374          ROOT NO. 3     -0.119    -0.116
ROOT NO. 2    -1.588    2.374          ROOT NO. 1     -0.119     0.116

K=      0.800
  D[0]D[1]D[2]+KN[0]N[1]N[2]=

  9.170E 01  1.692E 03  1.174E 04  3.5[illegible]E 04  [illegible]E 04  [illegible]E 04
  1.840E 03
               Real    Imaginary                        Real    Imaginary
ROOT NO. 6    -7.512   -3.068          ROOT NO. 5     [illegible]   [illegible]
ROOT NO. 4    -1.520   -2.692          ROOT NO. 3     [illegible]   [illegible]
ROOT NO. 2    -1.520    2.692          ROOT NO. 1     [illegible]   [illegible]
```

```
K=      1.000
    D[0]D[1]D[2]+KN[0]N[1]N[2]=

      9.170E 01   1.692E 03   1.174E 04   3.708E 04   7.741E 04   [illegible]
      1.971E 03
                    Real     Imaginary                              Real      Imaginary
  ROOT NO. 6    -7.528    -2.902            ROOT NO. 5   -1.476    -2.894
  ROOT NO. 4    -7.528     2.902            ROOT NO. 3   [illegible]   -0.000
  ROOT NO. 2    -1.476     2.894            ROOT NO. 1   [illegible]   0.000

K=      2.000
    D[0]D[1]D[2]+KN[0]N[1]N[2]=

      9.170E 01   1.692E 03   1.174E 04   4.332E 04   1.141E 05   5.602E 04
      2.626E 03
                    Real     Imaginary                              Real      Imaginary
  ROOT NO. 6    -1.253    -3.784            ROOT NO. 5   -7.671     2.031
  ROOT NO. 4    -7.671    -2.031            ROOT NO. 3   -0.052     0.000
  ROOT NO. 2    -1.253     3.784            ROOT NO. 1   -0.547     0.000

K=      3.000
    D[0]D[1]D[2]+KN[0]N[1]N[2]=

      9.170E 01   1.692E 03   1.174E 04   [illegible]E 04   1.508E 05   8.339E 04
      3.281E 03
                    Real     Imaginary                              Real      Imaginary
  ROOT NO. 6    -1.021    -4.491            ROOT NO. 5   -7.865     0.902
  ROOT NO. 4    -7.865    -0.902            ROOT NO. 3   -0.043    -0.000
  ROOT NO. 2    -1.021     4.491            ROOT NO. 1   -0.632     0.000

K=      4.000
    D[0]D[1]D[2]+KN[0]N[1]N[2]=

      9.170E 01   1.692E 03   1.174E 04   5.580E 04   1.874E 05   1.108E 05
      3.936E 03
                    Real     Imaginary                              Real      Imaginary
  ROOT NO. 6    -0.797    -5.067            ROOT NO. 5   -9.423     0.000
  ROOT NO. 4    -6.712     0.000            ROOT NO. 3   -0.038    -0.000
  ROOT NO. 2    -0.797     5.067            ROOT NO. 1   -0.680     0.000

K=      5.000
    D[0]D[1]D[2]+KN[0]N[1]N[2]=

      9.170E 01   1.692E 03   1.174E 04   6.204E 04   2.241E 05   1.381E 05
      4.591E 03
                    Real     Imaginary                              Real      Imaginary
  ROOT NO. 6    -0.589    -5.551            ROOT NO. 5  -10.280     0.000
  ROOT NO. 4    -6.244    -0.000            ROOT NO. 3   -0.035    -0.000
  ROOT NO. 2    -0.589     5.551            ROOT NO. 1   -0.710     0.000

K=      6.000
    D[0]D[1]D[2]+KN[0]N[1]N[2]=

      9.170E 01   1.692E 03   1.174E 04   6.828E 04   2.607E 05   1.655E 05
      5.246E 03
                    Real     Imaginary                              Real      Imaginary
  ROOT NO. 6    -0.396    -5.971            ROOT NO. 5  -10.901     0.000
  ROOT NO. 4    -5.989     0.000            ROOT NO. 3   -0.033     0.000
  ROOT NO. 2    -0.396     5.971            ROOT NO. 1   -0.732    -0.000

K=      7.000
    D[0]D[1]D[2]+KN[0]N[1]N[2]=

      9.170E 01   1.692E 03   1.174E 04   7.452E 04   2.974E 05   1.929E 05
      5.901E 03
                    Real     Imaginary                              Real      Imaginary
  ROOT NO. 6    -0.213    -6.344            ROOT NO. 5  -11.409    -0.000
  ROOT NO. 4    -5.323    -0.000            ROOT NO. 3   -0.032     0.000
  ROOT NO. 2    -0.218     6.344            ROOT NO. 1   -0.747     0.000

K=      8.000
    D[0]D[1]D[2]+KN[0]N[1]N[2]=

      9.170E 01   1.692E 03   1.174F 04   8.076E 04   3.340E 05   2.202E 05
      6.556E 03
                    Real     Imaginary                              Real      Imaginary
  ROOT NO. 6    -0.052    -6.679            ROOT NO. 5  -11.345     0.000
  ROOT NO. 4    -5.706     0.000            ROOT NO. 3   -0.031    -0.000
  ROOT NO. 2    -0.052     6.679            ROOT NO. 1   -0.759    -0.000
```

```
K=      7.000
   D[0]D[1]D[2]+KN[0]N[1]N[2]=

     9.170E 01   1.692E 03   1.174E 04   7.452E 04   2.[illegible]74E 05   1.[illegible]E 05
     5.901E 03
                   Real      Imaginary                       Real      Imaginary
  ROOT NO. 6    -0.218     -6.344          ROOT NO. 5   -11.408    -0.000
  ROOT NO. 4    -5.823     -0.000          ROOT NO. 3    -0.032     0.000
  ROOT NO. 2    -0.218      6.344          ROOT NO. 1    -0.747     0.000

K=      8.000
   D[0]D[1]D[2]+KN[0]N[1]N[2]=

     9.170E 01   1.692E 03   1.174E 04   8.076E 04   3.240E 05   2.202E 05
     6.556E 03
                   Real      Imaginary                       Real      Imaginary
  ROOT NO. 6    -0.053     -6.679          ROOT NO. 5   -11.845     0.000
  ROOT NO. 4    -5.706      0.[illegible]          ROOT NO. 3    -0.031    -0.000
  ROOT NO. 2    -0.053      6.679          ROOT NO. 1    -0.759    -0.000


K=      9.000
   D[0]D[1]D[2]+KN[0]N[1]N[2]=

     9.170E 01   1.692E 03   1.174E 04   8.700E 04   3.707E 05   2.476E 05
     7.211E 03
                   Real      Imaginary                       Real      Imaginary
  ROOT NO. 6     0.102     -6.986          ROOT NO. 5   -12.233    -0.000
  ROOT NO. 4    -0.031      0.000          ROOT NO. 3     0.102     6.[illegible]
  ROOT NO. 2    -5.618      0.000          ROOT NO. 1    -0.768    -0.000

K=     10.000
   D[0]D[1]D[2]+KN[0]N[1]N[2]=

     9.170E 01   1.692E 03   1.174E 04   9.324E 04   4.073E 05   2.750E 05
     7.866E 03
                   Real      Imaginary                       Real      Imaginary
  ROOT NO. 6     0.247     -7.268          ROOT NO. 5   -12.584    -0.000
  ROOT NO. 4    -0.030      0.000          ROOT NO. 3     0.247     7.268
  ROOT NO. 2    -5.550     -0.000          ROOT NO. 1    -0.776    -0.000
```

D.1.2 WITHOUT PRESSURE SENSOR (POSITION COMMAND)

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**************************************************************
                           DELTA P THEORETICAL ANALYSIS
**************************************************************

N0(S) COEFFICIENTS
  1.000E 01
D0(S) COEFFICIENTS
  1.000E 00  1.000E 01
N1(S) COEFFICIENTS
  6.240E 02  5.448E 02  1.310E 01
D1(S) COEFFICIENTS
  9.170E 01  3.161E 02  5.800E 02  1.420E 01  1.880E 01
N2(S) COEFFICIENTS
  1.000E 00
D2(S) COEFFICIENTS
  1.000E 00


N[0]N[1]D[2]=

  6.240E 03  5.448E 03  1.310E 02
N[0]N[1]N[2]=

  6.240E 03  5.448E 03  1.310E 02
               Real     Imaginary                     Real     Imaginary
ROOT NO. 2   -0.025     0.000          ROOT NO. 1   -0.848     0.000

K=     0.000
  D[0]D[1]D[2]+KN[0]N[1]N[2]=

  9.170E 01  1.233E 03  3.741E 03  5.814E 03  1.608E 02  1.880E 02
               Real     Imaginary                     Real     Imaginary
ROOT NO. 5   -1.720    -1.819          ROOT NO. 4  -10.000    -0.000
ROOT NO. 3   -0.003    -0.181          ROOT NO. 2   -1.720     1.819
ROOT NO. 1   -0.003     0.181


K=     0.200
  D[0]D[1]D[2]+KN[0]N[1]N[2]=

  9.170E 01  1.233E 03  3.741E 03  7.062E 03  1.250E 03  2.142E 02
               Real     Imaginary                     Real     Imaginary
ROOT NO. 5   -1.552    -2.111          ROOT NO. 4  -10.167     0.000
ROOT NO. 3   -0.089    -0.160          ROOT NO. 2   -1.552     2.111
ROOT NO. 1   -0.089     0.160

K=     0.500
  D[0]D[1]D[2]+KN[0]N[1]N[2]=

  9.170E 01  1.233E 03  3.741E 03  8.934E 03  2.885E 03  2.535E 02
               Real     Imaginary                     Real     Imaginary
ROOT NO. 5   -1.345    -2.504          ROOT NO. 4  -10.397     0.000
ROOT NO. 3   -0.180    -0.021          ROOT NO. 2   -1.345     2.504
ROOT NO. 1   -0.180     0.021

K=     0.800
  D[0]D[1]D[2]+KN[0]N[1]N[2]=

  9.170E 01  1.233E 03  3.741E 03  1.081E 04  4.519E 03  2.928E 02
               Real     Imaginary                     Real     Imaginary
ROOT NO. 5   -1.181    -2.849          ROOT NO. 4  -10.607     0.000
ROOT NO. 3   -0.079     0.000          ROOT NO. 2   -1.181     2.849
ROOT NO. 1   -0.398     0.000
```

C - 3

```
K=      1.000
    D[0]D[1]D[2]+KN[0]N[1]N[2]=

      9.170E 01   1.233E 03   3.741E 03   1.205E 04   5.609E 03   3.190E 02
                     Real      Imaginary                   Real     Imaginary
  ROOT NO. 5     -1.088      -3.056           ROOT NO. 4   -10.739    -0.000
  ROOT NO. 3     -0.066       0.000           ROOT NO. 2    -1.088     3.056
  ROOT NO. 1     -0.466       0.000

K=      2.000
    D[0]D[1]D[2]+KN[0]N[1]N[2]=

      9.170E 01   1.233E 03   3.741E 03   1.829E 04   1.106E 04   4.500E 02
                     Real      Imaginary                   Real     Imaginary
  ROOT NO. 5     -0.728      -3.892           ROOT NO. 4   -11.317     0.000
  ROOT NO. 3     -0.044       0.000           ROOT NO. 2    -0.728     3.892
  ROOT NO. 1     -0.631      -0.000

K=      3.000
    D[0]D[1]D[2]+KN[0]N[1]N[2]=

      9.170E 01   1.233E 03   3.741E 03   2.453E 04   1.650E 04   5.810E 02
                     Real      Imaginary                   Real     Imaginary
  ROOT NO. 5     -0.456      -4.525           ROOT NO. 4   -11.802    -0.000
  ROOT NO. 3     -0.037      -0.000           ROOT NO. 2    -0.456     4.525
  ROOT NO. 1     -0.697      -0.000

K=      4.000
    D[0]D[1]D[2]+KN[0]N[1]N[2]=

      9.170E 01   1.233E 03   3.741E 03   3.077E 04   2.195E 04   7.120E 02
                     Real      Imaginary                   Real     Imaginary
  ROOT NO. 5     -0.228      -5.043           ROOT NO. 4   -12.225    -0.000
  ROOT NO. 3     -0.034      -0.000           ROOT NO. 2    -0.228     5.043
  ROOT NO. 1     -0.732      -0.000

K=      5.000
    D[0]D[1]D[2]+KN[0]N[1]N[2]=

      9.170E 01   1.233E 03   3.741E 03   3.701E 04   2.740E 04   8.430E 02
                     Real      Imaginary                   Real     Imaginary
  ROOT NO. 5     -0.029      -5.485           ROOT NO. 4   -12.603     0.000
  ROOT NO. 3     -0.032       0.000           ROOT NO. 2    -0.029     5.485
  ROOT NO. 1     -0.754       0.000

K=      6.000
    D[0]D[1]D[2]+KN[0]N[1]N[2]=

      9.170E 01   1.233E 03   3.741E 03   4.325E 04   3.285E 04   9.740E 02
                     Real      Imaginary                   Real     Imaginary
  ROOT NO. 5      0.149      -5.873           ROOT NO. 4   -12.946     0.000
  ROOT NO. 3     -0.031       0.000           ROOT NO. 2     0.149     5.873
  ROOT NO. 1     -0.769      -0.000

K=      7.000
    D[0]D[1]D[2]+KN[0]N[1]N[2]=

      9.170E 01   1.233E 03   3.741E 03   4.949E 04   3.830E 04   1.105E 03
                     Real      Imaginary                   Real     Imaginary
  ROOT NO. 5      0.312      -6.222           ROOT NO. 4   -13.261     0.000
  ROOT NO. 3     -0.030       0.000           ROOT NO. 2     0.312     6.222
  ROOT NO. 1     -0.780      -0.000

K=      8.000
    D[0]D[1]D[2]+KN[0]N[1]N[2]=

      9.170E 01   1.233E 03   3.741E 03   5.573E 04   4.374E 04   1.236E 03
                     Real      Imaginary                   Real     Imaginary
  ROOT NO. 5      0.462      -6.540           ROOT NO. 4   -13.554     0.000
  ROOT NO. 3     -0.029       0.000           ROOT NO. 2     0.462     6.540
  ROOT NO. 1     -0.788       0.000
```

```
K=      9.000
    D[0]D[1]D[2]+KN[0]N[1]N[2]=

      9.170E 01  1.233E 03  3.741E 03  6.197E 04  4.919E 04  1.367E 03
                  Real     Imaginary                  Real    Imaginary
  ROOT NO. 5     0.603     -6.332          ROOT NO. 4  -13.829   -0.000
  ROOT NO. 3    -0.029      0.000          ROOT NO. 2    0.603    6.832
  ROOT NO. 1    -0.795     -0.000

K=     10.000
    D[0]D[1]D[2]+KN[0]N[1]N[2]=

      9.170E 01  1.233E 03  3.741E 03  6.821E 04  5.464E 04  1.498E 03
                  Real     Imaginary                  Real    Imaginary
  ROOT NO. 5     0.734     -7.104          ROOT NO. 4  -14.087   -0.000
  ROOT NO. 3    -0.028     -0.000          ROOT NO. 2    0.734    7.104
  ROOT NO. 1    -0.800      0.000
```

D.2 HIGH DYNAMIC PRESSURE

```
**********************************************************
              DELTA P FREQUENCY ANALYSIS FC1
**********************************************************

                     INPUT DATA

 Wing Area (D[80],ft↑2)                         174.0000000
 Weight (D[71],lb)                             2645.0000000
 Wing Span (D[72],ft)                            35.8000000
 MAC (D[73],ft)                                   4.9000000
 Airspeed (D[74],ft/s)                          272.8000000
 Density (D[75],slugs/ft↑3)                       0.0020500
 Angle of attack (D[76],rad)                      0.0000000
 Theta initial (D[77],rad)                        0.0000000
 Iyb (D[81],slugs-ft↑2)                        1346.0000000
 CL1 (D[95])                                      0.3100000
 CD1 (D[96])                                      0.0310000
 CXT1 (D[97])                                     0.0310000
 CM1 (D[88])                                      0.0000000
 CMT1 (D[89])                                     0.0000000

 Nondimensional derivatives        Dimensional derivatives

                LONGITUDINAL DERIVATIVES

  CDU (D[1])        0.0000        XU (1/s)          -0.0367
  CXTU (D[2])      -0.0930        XTU (1/s)         -0.0183
  CDA (D[3])        0.1300        XA (ft/s↑2)       29.0612
  CDDE (D[4])       0.0600        XDE (ft/s↑2)      -9.6871
  CLU (D[6])        0.0000        ZU (1/s)          -0.3669
  CLA (D[7])        4.6000        ZA (ft/s↑2)     -747.6804
  CLAD (D[8])       1.7000        ZAD (ft/s)        -2.4650
  CLQ (D[9])        3.9000        ZQ (ft/s)         -5.6549
  CLDE (D[10])      0.4300        ZDE (ft/s↑2)     -69.4240
  CMU (D[12])       0.0000        MU (1/fts)         0.0000
  CMTU (D[13])      0.0000        MTU (1/fts)        0.0000
  CMA (D[14])      -0.8900        MA (1/s↑2)       -43.0034
  CMTA (D[15])      0.0000        MTA (1/s↑2)        0.0000
  CMAD (D[16])     -5.2000        MAD (1/s)         -2.3565
  CMQ (D[17])     -12.4000        MQ (1/s)          -5.3809
  CMDE (D[18])     -1.2800        MDE (1/s↑2)      -61.8476
```

```
*********************************************************************
                    DELTA P FREQUENCY ANALYSIS FC1
*********************************************************************

        TRANSFER FUNCTION POLYNOMIAL COEFFICIENTS

      THE COEFFICIENTS OF THE LONGITUDINAL CHARACTERISTIC EQUATION ARE:
 --  A=      275.26497   B=      2846.82537   C=     15677.67370
     D=      937.76723   E=       507.68751

             THE COEFFICIENTS OF THE NUMERATOR U(S) ARE:
              0.00000  AU=     -2666.51129  BU=    -29448.17973
    CU=    -98568.06981  DU=  1391743.28340

            THE COEFFICIENTS OF THE NUMERATOR ALPHA(S) ARE:
              0.00000  AA=       -69.42401  BA=    -16896.11195
    CA=      -910.82371  DA=      -730.15732

          THE COEFFICIENTS OF THE NUMERATOR THETA(S) ARE:
              0.00000              0.00000  AT=    -16867.82100
    BT=    -44193.19758  CT=     -3193.23231

STANDARD FORMAT FOR LONGITUDINAL TRANSFER FUNCTIONS


 U(S)/DELTA-E(S) COEFFICIENTS ARE:

         KUDE      2741.33843
          TU1        -0.21267
        OMN U        10.53575
         ZT U         0.74725
       OMN SP         7.50749
        ZT SP         0.68516
        OMN P         0.18090
         ZT P         0.15056

 ALPHA(S)/DELTA-E(S) COEFFICIENTS ARE:

     KALPHADE        -1.43820
      TALPHA1         0.00411
    OMN ALPHA         0.20790
     ZT ALPHA         0.12923
       OMN SP         7.50749
        ZT SP         0.68516
        OMN P         0.18090
         ZT P         0.15056

 THETA(S)/DELTA-E(S) COEFFICIENTS ARE:

     KTHETADE        -6.28976
      TTHETA1        13.44681
      TTHETA2         0.39383
       OMN SP         7.50749
        ZT SP         0.68516
        OMN P         0.18090
         ZT P         0.15056
```

D.2.1 WITH PRESSURE SENSOR (PRESSURE COMMAND)

```
*****************************************************
                    DELTA P FREQUENCY ANALYSIS FC1
*****************************************************

N0(S) COEFFICIENTS
  1.000E 01  5.000E 01
D0(S) COEFFICIENTS
  1.000E 00  1.500E 01  2.295E 02
N1(S) COEFFICIENTS
  1.687E 04  4.419E 04  3.193E 03
D1(S) COEFFICIENTS
  2.753E 02  2.847E 03  1.568E 04  9.378E 02  5.077E 02
N2(S) COEFFICIENTS
  1.000E 00
D2(S) COEFFICIENTS
  1.000E 00


N[ 0 ]N[ 1 ]D[ 2 ]=

  1.687E 05  1.285E 06  2.242E 06  1.597E 05
N[ 0 ]N[ 1 ]N[ 2 ]=

  1.687E 05  1.285E 06  2.242E 06  1.597E 05
              Real    Imaginary                    Real     Imaginary
ROOT NO. 3   -0.074    0.000        ROOT NO. 2    -5.000    0.000
ROOT NO. 1   -2.546    0.000

K=     0.000
    D[ 0 ]D[ 1 ]D[ 2 ]+KN[ 0 ]N[ 1 ]N[ 2 ]=

  2.753E 02  6.976E 03  1.216E 05  8.894E 05  3.613E 06  2.228E 05
  1.165E 05
              Real    Imaginary                    Real     Imaginary
ROOT NO. 6   -7.500  -13.162        ROOT NO. 5    -5.143   -5.468
ROOT NO. 4   -7.500   13.162        ROOT NO. 3    -5.143    5.468
ROOT NO. 2   -0.027   -0.179        ROOT NO. 1    -0.027    0.179

K=     0.200
    D[ 0 ]D[ 1 ]D[ 2 ]+KN[ 0 ]N[ 1 ]N[ 2 ]=

  2.753E 02  6.976E 03  1.216E 05  9.232E 05  3.870E 06  6.712E 05
  1.484E 05
              Real    Imaginary                    Real     Imaginary
ROOT NO. 6   -7.129  -13.026        ROOT NO. 5    -7.129   13.026
ROOT NO. 4   -5.455   -5.600        ROOT NO. 3    -5.455    5.600
ROOT NO. 2   -0.086   -0.181        ROOT NO. 1    -0.086    0.181

K=     0.500
    D[ 0 ]D[ 1 ]D[ 2 ]+KN[ 0 ]N[ 1 ]N[ 2 ]=

  2.753E 02  6.976E 03  1.216E 05  9.738E 05  4.255E 06  1.344E 06
  1.963E 05
              Real    Imaginary                    Real     Imaginary
ROOT NO. 6   -6.513  -12.886        ROOT NO. 5    -5.993   -5.725
ROOT NO. 4   -6.513   12.886        ROOT NO. 3    -5.993    5.725
ROOT NO. 2   -0.165   -0.151        ROOT NO. 1    -0.165    0.151

K=     0.800
    D[ 0 ]D[ 1 ]D[ 2 ]+KN[ 0 ]N[ 1 ]N[ 2 ]=

  2.753E 02  6.976E 03  1.216E 05  1.024E 06  4.641E 06  2.016E 06
  2.442E 05
              Real    Imaginary                    Real     Imaginary
ROOT NO. 6   -5.857  -12.859        ROOT NO. 5    -6.579   -5.723
ROOT NO. 4   -5.857   12.859        ROOT NO. 3    -0.234   -0.059
ROOT NO. 2   -6.579    5.723        ROOT NO. 1    -0.234    0.059
```

```
K=     1.000
 D[0]D[1]D[2]+KN[0]N[1]N[2]=

     2.753E 02  6.976E 03  1.216E 05  1.058E 06  4.898E 06  2.464E 06
     2.762E 05
                   Real    Imaginary                        Real    Imaginary
  ROOT NO. 6    -5.428   -12.910          ROOT NO. 5   -6.966   -5.646
  ROOT NO. 4    -5.428    12.910          ROOT NO. 3   -0.163   -0.000
  ROOT NO. 2    -6.966     5.646          ROOT NO. 1   -0.390    0.000

K=     2.000
 D[0]D[1]D[2]+KN[0]N[1]N[2]=

     2.753E 02  6.976E 03  1.216E 05  1.227E 06  6.183E 06  4.706E 06
     4.358E 05
                   Real    Imaginary                        Real    Imaginary
  ROOT NO. 6    -3.720   -13.588          ROOT NO. 5   -3.720   13.588
  ROOT NO. 4    -8.505    -4.726          ROOT NO. 3   -0.107    0.000
  ROOT NO. 2    -8.505     4.726          ROOT NO. 1   -0.784    0.000

K=     3.000
 D[0]D[1]D[2]+KN[0]N[1]N[2]=

     2.753E 02  6.976E 03  1.216E 05  1.395E 06  7.469E 06  6.948E 06
     5.955E 05
                   Real    Imaginary                        Real    Imaginary
  ROOT NO. 6    -2.572   -14.384          ROOT NO. 5   -9.533   -3.408
  ROOT NO. 4    -2.572    14.384          ROOT NO. 3   -0.095   -0.000
  ROOT NO. 2    -9.533     3.408          ROOT NO. 1   -1.037   -0.000

K=     4.000
 D[0]D[1]D[2]+KN[0]N[1]N[2]=

     2.753E 02  6.976E 03  1.216E 05  1.564E 06  8.754E 06  9.189E 06
     7.552E 05
                   Real    Imaginary                        Real    Imaginary
  ROOT NO. 6    -1.707   -15.119          ROOT NO. 5   -1.707   15.119
  ROOT NO. 4   -10.307    -1.336          ROOT NO. 3   -0.090   -0.000
  ROOT NO. 2   -10.307     1.336          ROOT NO. 1   -1.223   -0.000

K=     5.000
 D[0]D[1]D[2]+KN[0]N[1]N[2]=

     2.753E 02  6.976E 03  1.216E 05  1.733E 06  1.004E 07  1.143E 07
     9.148E 05
                   Real    Imaginary                        Real    Imaginary
  ROOT NO. 6    -1.007   -15.788          ROOT NO. 5  -13.618   -0.000
  ROOT NO. 4    -0.087     0.000          ROOT NO. 3   -1.007   15.788
  ROOT NO. 2    -8.258    -0.000          ROOT NO. 1   -1.365    0.000

K=     6.000
 D[0]D[1]D[2]+KN[0]N[1]N[2]=

     2.753E 02  6.976E 03  1.216E 05  1.902E 06  1.132E 07  1.367E 07
     1.074E 06
                   Real    Imaginary                        Real    Imaginary
  ROOT NO. 6    -0.412   -16.399          ROOT NO. 5  -15.408    0.000
  ROOT NO. 4    -0.084    -0.000          ROOT NO. 3   -0.412   16.399
  ROOT NO. 2    -7.546     0.000          ROOT NO. 1   -1.478   -0.000

K=     7.000
 D[0]D[1]D[2]+KN[0]N[1]N[2]=

     2.753E 02  6.976E 03  1.216E 05  2.070E 06  1.261E 07  1.591E 07
     1.234E 06
                   Real    Imaginary                        Real    Imaginary
  ROOT NO. 6     0.107   -16.962          ROOT NO. 5  -16.765   -0.000
  ROOT NO. 4    -0.083    -0.000          ROOT NO. 3    0.107   16.962
  ROOT NO. 2    -7.136     0.000          ROOT NO. 1   -1.570   -0.000
```

```
K=      8.000
    D[0]D[1]D[2]+KN[0]N[1]N[2]=

      2.753E 02  6.976E 03  1.216E 05  2.239E 06  1.390E 07  1.816E 07
      1.394E 06
                    Real    Imaginary                     Real   Imaginary
  ROOT NO. 6       0.570   -17.487          ROOT NO. 5  -17.894    0.000
  ROOT NO. 4      -0.082    -0.000          ROOT NO. 3    0.570   17.487
  ROOT NO. 2      -6.857     0.000          ROOT NO. 1   -1.647    0.000

K=      9.000
    D[0]D[1]D[2]+KN[0]N[1]N[2]=

      2.753E 02  6.976E 03  1.216E 05  2.408E 06  1.518E 07  2.040E 07
      1.553E 06
                    Real    Imaginary                     Real   Imaginary
  ROOT NO. 6       0.989   -17.977          ROOT NO. 5  -18.875    0.000
  ROOT NO. 4      -0.081    -0.000          ROOT NO. 3    0.989   17.977
  ROOT NO. 2      -6.651     0.000          ROOT NO. 1   -1.712   -0.000

K=     10.000
    D[0]D[1]D[2]+KN[0]N[1]N[2]=

      2.753E 02  6.976E 03  1.216E 05  2.576E 06  1.647E 07  2.264E 07
      1.713E 06
                    Real    Imaginary                     Real   Imaginary
  ROOT NO. 6       1.373   -18.439          ROOT NO. 5  -19.749    0.000
  ROOT NO. 4      -0.080     0.000          ROOT NO. 3    1.373   18.439
  ROOT NO. 2      -6.490    -0.000          ROOT NO. 1   -1.768    0.000
```

D.2.2 WITHOUT PRESSURE SENSOR (POSITION COMMAND)

```
*****************************************************
                       DELTA P FREQUENCY ANALYSIS
*****************************************************


NO(S) COEFFICIENTS
  1.000E 01
DO(S) COEFFICIENTS
  1.000E 00  1.000E 01
N1(S) COEFFICIENTS
  1.687E 04  4.419E 04  3.193E 03
D1(S) COEFFICIENTS
  2.753E 02  2.847E 03  1.568E 04  9.378E 02  5.077E 02
N2(S) COEFFICIENTS
  1.000E 00
D2(S) COEFFICIENTS
  1.000E 00



N[ 0 ]N[ 1 ]D[ 2 ]=

  1.687E 05  4.419E 05  3.193E 04
N[ 0 ]N[ 1 ]N[ 2 ]=

  1.687E 05  4.419E 05  3.193E 04
                Real     Imaginary                       Real     Imaginary
ROOT NO. 2     -0.074    0.000          ROOT NO. 1     -1.546    0.000

K=     0.000
  D[ 0 ]D[ 1 ]D[ 2 ]+KN[ 0 ]N[ 1 ]N[ 2 ]=

  2.753E 02  5.600E 03  4.415E 04  1.577E 05  9.886E 03  5.077E 03
                Real     Imaginary                       Real     Imaginary
ROOT NO. 5     -5.143   -5.468          ROOT NO. 4    -10.000    0.000
ROOT NO. 3     -5.143    5.468          ROOT NO. 2     -0.027   -0.179
ROOT NO. 1     -0.027    0.179


K=     0.200
  D[ 0 ]D[ 1 ]D[ 2 ]+KN[ 0 ]N[ 1 ]N[ 2 ]=

  2.753E 02  5.600E 03  4.415E 04  1.915E 05  9.827E 04  1.146E 04
                Real     Imaginary                       Real     Imaginary
ROOT NO. 5     -4.196   -5.994          ROOT NO. 4    -11.380    0.000
ROOT NO. 3     -0.172    0.000          ROOT NO. 2     -4.196    5.994
ROOT NO. 1     -0.397    0.000

K=     0.500
  D[ 0 ]D[ 1 ]D[ 2 ]+KN[ 0 ]N[ 1 ]N[ 2 ]=

  2.753E 02  5.600E 03  4.415E 04  2.421E 05  2.309E 05  2.104E 04
                Real     Imaginary                       Real     Imaginary
ROOT NO. 5     -3.209   -6.779          ROOT NO. 4    -12.777   -0.000
ROOT NO. 3     -0.102   -0.000          ROOT NO. 2     -3.209    6.779
ROOT NO. 1     -1.044    0.000

K=     0.800
  D[ 0 ]D[ 1 ]D[ 2 ]+KN[ 0 ]N[ 1 ]N[ 2 ]=

  2.753E 02  5.600E 03  4.415E 04  2.927E 05  3.634E 05  3.062E 04
                Real     Imaginary                       Real     Imaginary
ROOT NO. 5     -2.512   -7.489          ROOT NO. 4    -13.804   -0.000
ROOT NO. 3     -0.091   -0.000          ROOT NO. 2     -2.512    7.489
ROOT NO. 1     -1.422   -0.000
```

```
K=      1.000
    D[0]D[1]D[2]+KN[0]N[1]N[2]=

      2.753E 02  5.600E 03  4.415E 04  3.264E 05  4.518E 05  3.701E 04
                   Real     Imaginary                  Real     Imaginary
  ROOT NO. 5    -2.144    -7.915           ROOT NO. 4  -14.374   0.000
  ROOT NO. 3    -0.087     0.000           ROOT NO. 2   -2.144   7.915
  ROOT NO. 1    -1.592     0.000

K=      2.000
    D[0]D[1]D[2]+KN[0]N[1]N[2]=

      2.753E 02  5.600E 03  4.415E 04  4.951E 05  8.937E 05  6.894E 04
                   Real     Imaginary                  Real     Imaginary
  ROOT NO. 5    -0.869    -9.619           ROOT NO. 4  -16.508   0.000
  POOT NO. 3    -0.869     9.619           ROOT NO. 2   -0.081   0.000
  ROOT NO. 1    -2.015     0.000

K=      3.000
    D[0]D[1]D[2]+KN[0]N[1]N[2]=

      2.753E 02  5.600E 03  4.415E 04  6.638E 05  1.336E 06  1.009E 05
                   Real     Imaginary                  Real     Imaginary
  ROOT NO. 5    -0.022   -10.888           ROOT NO. 4  -18.038  -0.000
  ROOT NO. 3    -0.079     0.000           ROOT NO. 2   -0.022  10.888
  ROOT NO. 1    -2.181     0.000

K=      4.000
    D[0]D[1]D[2]+KN[0]N[1]N[2]=

      2.753E 02  5.600E 03  4.415E 04  8.324E 05  1.778E 06  1.328E 05
                   Real     Imaginary                  Real     Imaginary
  ROOT NO. 5     0.635   -11.917           ROOT NO. 4  -19.265  -0.000
  ROOT NO. 3    -0.078     0.000           ROOT NO. 2    0.635  11.917
  ROOT NO. 1    -2.268     0.000

K=      5.000
    D[0]D[1]D[2]+KN[0]N[1]N[2]=

      2.753E 02  5.600E 03  4.415E 04  1.001E 06  2.220E 06  1.647E 05
                   Real     Imaginary                  Real     Imaginary
  ROOT NO. 5     1.181   -12.795           ROOT NO. 4  -20.304  -0.000
  ROOT NO. 3    -0.077     0.000           ROOT NO. 2    1.181  12.795
  ROOT NO. 1    -2.322     0.000

K=      6.000
    D[0]D[1]D[2]+KN[0]N[1]N[2]=

      2.753E 02  5.600E 03  4.415E 04  1.170E 06  2.661E 06  1.967E 05
                   Real     Imaginary                  Real     Imaginary
  ROOT NO. 5     1.654   -13.566           ROOT NO. 4  -21.214  -0.000
  ROOT NO. 3    -0.076     0.000           ROOT NO. 2    1.654  13.566
  ROOT NO. 1    -2.358     0.000

K=      7.000
    D[0]D[1]D[2]+KN[0]N[1]N[2]=

      2.753E 02  5.600E 03  4.415E 04  1.338E 06  3.103E 06  2.286E 05
                   Real     Imaginary                  Real     Imaginary
  ROOT NO. 5     2.074   -14.257           ROOT NO. 4  -22.029  -0.000
  ROOT NO. 3    -0.076     0.000           ROOT NO. 2    2.074  14.257
  ROOT NO. 1    -2.384     0.000

K=      8.000
    D[0]D[1]D[2]+KN[0]N[1]N[2]=

      2.753E 02  5.600E 03  4.415E 04  1.507E 06  3.545E 06  2.605E 05
                   Real     Imaginary                  Real     Imaginary
  ROOT NO. 5     2.455   -14.388           ROOT NO. 4  -22.770   0.000
  ROOT NO. 3    -0.076     0.000           ROOT NO. 2    2.455  14.388
  ROOT NO. 1    -2.404     0.000
```

```
K=      9.000
    D[0]D[1]D[2]+KN[0]N[1]N[2]=

      2.753E 02  5.600E 03  4.415E 04  1.676E 06  3.997E 06  2.925E 05
                 Real    Imaginary                       Real     Imaginary
  ROOT NO. 5     2.803  -15.468          ROOT NO. 4  -23.452   -0.000
  ROOT NO. 3    -0.076    0.000          ROOT NO. 2    2.803   15.468
  ROOT NO. 1    -2.420    0.000

K=     10.000
    D[0]D[1]D[2]+KN[0]N[1]N[2]=

      2.753E 02  5.600E 03  4.415E 04  1.844E 06  4.429E 06  3.244E 05
                 Real    Imaginary                       Real     Imaginary
  ROOT NO. 5     3.126  -16.008          ROOT NO. 4  -24.085   -0.000
  ROOT NO. 3    -0.076    0.000          ROOT NO. 2    3.126   16.008
  ROOT NO. 1    -2.432    0.000
```